U.S.D.A.

SOIL CONSERVATION SERVICE

SURVEY REPORT

PECOS RIVER WATERSHED NEW MEXICO AND TEXAS

PROGRAM FOR RUNOFF AND WATERFLOW RETARDATION AND SOIL EROSION PREVENTION

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AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U.S.D.A. Soil Conservation Service

U. S. DEPARTMENT OF AGRICULTURE
JULY 1950

UNITED STATES DEPARTMENT OF AGRICULTURE

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SURVEY REPORT

3a

PECOS RIVER WATERSHED

NEW MEXICO AND TEXAS

3b

Program for Runoff and Waterflow Retardation
and Soil Erosion Prevention

Pursuant to the Act approved June 22, 1936 (49 Stat. 1570
as amended and supplemented by the Act approved
June 28, 1938 (52 Stat. 1215)

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July 1950

C O N T E N T S

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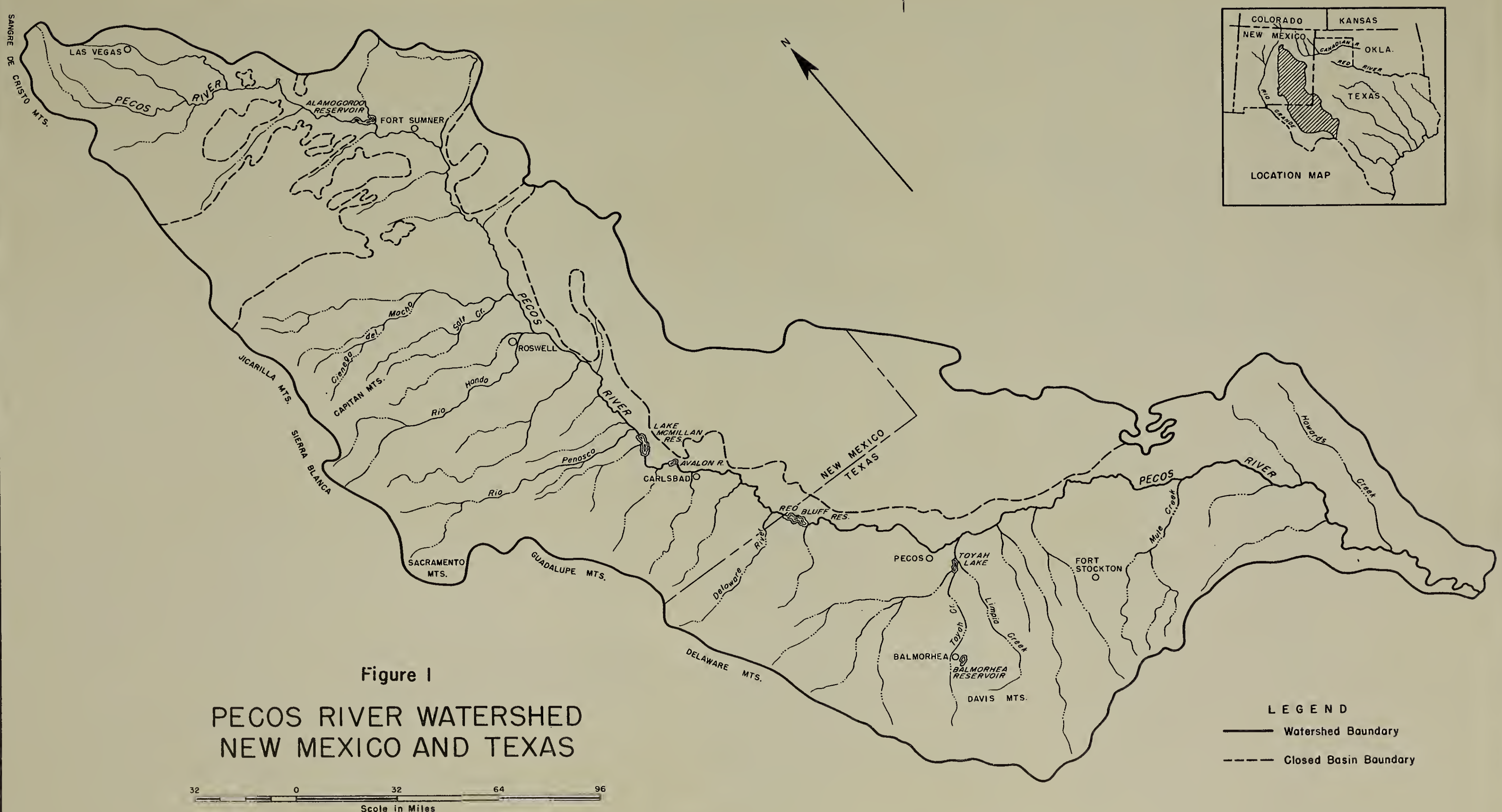

Figure I

PECOS RIVER WATERSHED NEW MEXICO AND TEXAS

Base Map Developed from Corps of Engineers, U.S. Army; Pecos River Joint Investigation; and Others.

MAY 1948

INTRODUCTION

Authority

This report is submitted under the provisions of the Act approved June 22, 1936 (49 Stat. 1570), as amended and supplemented by the Act approved June 28, 1938 (52 Stat. 1215).

Purpose and scope of Report

The purpose of this report is to outline a program of runoff and waterflow retardation and soil erosion prevention for the Pecos River Watershed in New Mexico and Texas, and to present recommendations for installing and maintaining the program, together with a comparison of its benefit and cost.

The Pecos River, a tributary of the Rio Grande, has a contributing drainage area of 33,200 square miles (21,260,800 acres.) This basin is situated in eastern New Mexico and western Texas (fig. 1).

RECOMMENDATIONS

It is recommended that a program of runoff and waterflow retardation and soil erosion prevention be installed during a 15-year period in the Pecos River Watershed in New Mexico and Texas at an estimated cost of $14,683,800 to the Federal Government, and at an estimated cost of $5,442,500 or its equivalent 1/ to local interests, making an estimated cost of $20,126,300 for the installation of the program.

The program will be operated and maintained at an estimated annual cost of $115,975 to the Federal Government and $221,865 or its equivalent to local interests, making an estimated total annual cost of $337,840 for operating and maintaining the program.

The recommended program is designed to reduce floodwater and sediment damage and to conserve soil and water resources. There are interdependent measures which will accomplish these objectives. They are: stabilizing and sediment control structures, diversion dikes and ditches, seeding range land, erosion control along roads, rodent control, adequate fire control, stockwater facilities, fencing, terracing, crop residue management, grass waterways, land leveling, erosion control structures on irrigated land, tributary channel control, channel improvement, land acquisition, and other soil and water conservation practices and measures applied in proper combination with the above listed measures which will make up a comprehensive program of soil and water conservation in accordance with the needs and capabilities of the land of the watershed.

1/ Labor, materials, equipment, land, easements, rights-of-way and other contributions in lieu of cash payments.

Educational assistance and technical services provided under this program will be synchronized and adapted toward the specific objectives of floodwater and sediment damage reductions.

The Secretary of Agriculture, or the head of any other Federal agency concerned, may make such modifications or substitutions of the measures described in this report as may be deemed advisable, due to changed physical or economic conditions or improved techniques, whenever he determines that such action will be in furtherance of the objectives of the recommended program.

The measures included in the recommended program will be installed on non-Federal land under cooperative arrangements with state and local governments, soil conservation districts, or other agencies acceptable to the Secretary of Agriculture.

The ratio of the estimated average annual value of the total benefit to the estimated average annual value of the total cost of the recommended program is 3.5 to 1. 1/

The program herein recommended includes the intensification, acceleration, or adaptation of certain activities under the current programs of Federal agencies in the watershed, and additional measures not now regularly carried out in such programs, all of which are necessary to complete a balanced runoff and waterflow retardation and erosion control program for the watershed. It is recommended that the Secretary of Agriculture be authorized to carry out all of this program except the part which is proposed for installation on land under the jurisdiction of a Federal agency other than the Department of Agriculture. It is further recommended that the head of such other Federal agency be authorized to carry out the part of the program which is proposed for installation on land under the jurisdiction of such agency. The extent to which the work recommended in this program for which the Secretary of Agriculture is to be responsible will be carried out under the Flood Control Act as requested herein or under other authorities will be considered by the Secretary in requesting appropriations for the prosecution of the program. Although the current activities of Federal agencies in the watershed which are primarily related to the objectives of the Flood Control Act are not included in the program herein specifically recommended, the program is based on the continuation of such activities at least at their present level. The extent to which the practices and measures included in the recommended program may be carried out by the acceleration, intensification, or adaptation of certain

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1/ Comparison of benefits and costs based on future price and cost levels assumed to prevail under an intermediate level of employment.

activities under the current programs of Federal agencies in the watershed will be taken into account in requesting appropriations for the prosecution of the program.

The Secretary of Agriculture or the head of any other Federal agency concerned may construct such buildings and other improvements as are needed to carry out the measures included in the recommended program.

The authority of the Secretary of Agriculture, or of the head of any other Federal agency concerned to prosecute the recommended program shall be supplemental to all other authority vested in him, and nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out any of the measures described herein or any other measures that are similar or related to the measures described herein.

DESCRIPTION OF WATERSHED

The Pecos River Watershed heads above Las Vegas in the mountains of north central New Mexico and extends southward across western Texas to the Rio Grande (fig. 1). The watershed contains about 33,200 square miles (21,260,800 acres), of which 17,300 square miles are in New Mexico and 15,900 are in Texas. This is the area which contributes surface flow to the main stream.

The Pecos River basin lies in the extreme southwestern portion of the Great Plains. It is bordered on the north by the Sangre de Cristo Mountain Range, on the west by foothills and by Jicarilla, Sierra Blanca, Sacramento, Guadalupe, Delaware, and Davis Mountains, and on the east by low foothills and the "Staked Plains." The drainage pattern is well developed. Streams in the northern and southern sections are deeply entrenched. The distinguishing feature of the middle basin is the large area 200 miles long and 10 to 30 miles wide which has nearly level or gently sloping topography. Elevations range from about 1,000 feet at the confluence of the Pecos River and Rio Grande to 13,000 feet in the Sangre de Cristo mountains (fig. 1).

The major tributary drainages are the Gallinas River, Rio Hondo, Rio Penasco, and Tecolote, Alamogordo, Cienega del Macho, Toyah and Limpia Creeks. Generally, these are intermittent streams, except in their upper reaches. The mountain sections of tributary channels are deep and have steep gradients which gradually flatten in the lower reaches.

Shallow soils 10 inches or less in depth occur on 55 percent of the watershed; medium depth soils of from 10 to 30 inches occupy 24 percent and deep soils of over 30 inches occur on 21 percent.

Generally the soils are medium to heavy textured. Short Grass Plains occupy 32 percent of the watershed, Desert Shrub Grassland 31 percent, Desert Grassland 18 percent, Pinon-Juniper Woodland 14 percent, and Coniferous Timber 5 percent. Erosion is severe on 7 percent of the watershed, moderate on 59 percent and slight on 34 percent.

U. S. Weather Bureau records of 6 to 35 years show that precipitation ranges from 10 to 12 inches in the central valleys to 35 inches or more in the mountainous areas. The mean annual temperature ranges from 69 degrees F. at Del Rio, Texas, to 41 degrees F. at Harvey's Ranch in the upper watershed. Temperatures ranging up to 114 degrees F. have been recorded at Barstow and Fort Stockton, Texas. A low temperature of minus 31 degrees F. has been recorded at Las Vegas, New Mexico. The growing season varies from 155 frost-free days at Las Vegas, New Mexico to 277 frost free days at Del Rio, Texas.

The population of the watershed was about 150,000 in 1940. About 92,000 persons resided in rural areas and 58,000 in urban centers. The rural population is concentrated in the upper tributary areas where the size of most of the farms is less than 15 acres. The 1940 census report shows that 67 percent of the population is in New Mexico and 33 percent in Texas.

Ninety-eight percent of the watershed is used for grazing and the remainder is cropland. The gross value of crops produced on irrigated land in 1948 is estimated at $26,000,000 and the gross value of crops produced in dry-farm land is estimated at $2,200,000. About $30,000,000 worth of livestock and livestock products were produced in 1948, and about $1,563,000 worth of timber products were harvested that year. Sixty-four percent of the land in the watershed is privately owned, 18 percent State owned, and 18 percent Federally owned or administered. All Federally owned or administered land is situated in New Mexico. This land includes national forests (5 percent of the watershed), public domain (11 percent), and Indian Reservation (2 percent). State land is found in both New Mexico and Texas.

The watershed was originally protected by a vegetative cover that retarded runoff and prevented soil erosion. Heavy grazing, particularly during the forepart of the 20th century and during drought periods, has resulted in the deterioration of the protective cover over much of the watershed. Plant vigor has been lowered and inferior grasses and shrubs have invaded the rangeland, changing the composition of the cover and reducing its effectiveness in retarding runoff. This change in range condition has occurred particularly in the lower elevations where undesirable brush has invaded large areas of grassland. Improper location of early roads and trails has contributed to valley trenching. As a result of the change in range condition runoff from

intense summer rainfall has been accelerated and sediment movement downstream has increased. Topsoil removed from the watershed by sheet and gully erosion and alluvium removed by valley trenching lodges in irrigation reservoirs, canals, and ditches. The deposition of infertile debris on highly developed farm land causes a heavy loss in crop production. Streambank erosion is also aggravated by the higher rate of runoff from watershed lands. Records show that a large part of the bank caving has occurred during the past 50 years.

FLOOD PROBLEMS

Floods in the Pecos River Watershed damage crops, farmland, irrigation systems, towns, highways, railroads, and utilities. During a 15-year period, 1932 to 1947, twelve floods in the watershed caused damage estimated at more than $9,000,000.

Floods usually occur during the season from May to October when growing crops are subject to damage. A major item of flood damage is the loss of crops. General storms produce high peak discharges in both the main stream and in tributaries. Although the high peak flows produced in the tributaries by local storms are reduced to non-damaging proportions after reaching the main stream, they transport considerable sediment into the main channel.

Agricultural losses due to floods have been confined largely to damage to crops by inundation, loss of land by streambank cutting, destruction of diversion dams, and sedimentation of reservoirs.

Four reservoirs located on the main channel of the Pecos River store water for irrigation projects which serve about 100,000 acres of land. The storage capacity of these and other off-channel reservoirs is being depleted by sediment. Sufficient storage capacity was provided in the major reservoirs to meet irrigation requirements of more than one year because of the need of carrying over a water supply into years of low flow. The capacity depletion results in increasing water losses by causing spills when stream flow is high. Sediment accumulation shortens the useful life of the reservoirs and thus adds to the cost of operating irrigation projects. Operation costs are increased by the expense of cleaning irrigation canals and ditches. Sediment accumulation on farmland results in expensive removal or land leveling operations.

Other kinds of flood damage are the destruction of homes, personal property, farm and ranch improvements, machinery and equipment, loss of livestock, loss of life (23 persons perished during the 1941 floods), loss of business, and less water for irrigation.

Table 1 shows the monetary evaluation of the average annual floodwater and sediment damage in the Pecos River Watershed.

Table 1

ESTIMATED AVERAGE ANNUAL MONETARY DAMAGES IN THE PECOS RIVER WATERSHED

Type of Damage	Average Annual Damages (1948 Prices)	
	(Dollars)	
Floodwater		
Agricultural - cropland, irrigation systems	454,900	
Nonagricultural - urban and public utility	100,300	
Sub-total		555,200
Sediment		
Reservoir sedimentation	377,800	
Sub-total		377,800
TOTAL AVERAGE ANNUAL DAMAGE		933,000

ACTIVITIES RELATED TO FLOOD CONTROL

Department of the Army, Corps of Engineers.--The Corps of Engineers is conducting a general flood control survey in the watershed. Recommendations contained herein have been correlated with the contemplated program of the Corps of Engineers in order to provide the most complete flood protection that is feasible. Particular attention has been given to the evaluation of program recommendations to avoid duplicating benefits credited to works of improvement under consideration by the Corps of Engineers.

Department of Interior.--The Bureau of Land Management administers more than 2 million acres of public domain grazing land within the Pecos River Watershed in New Mexico, pursuant to the Taylor Grazing Act of 1934. (There exists no public domain in the State of Texas.) Most of this public domain lies within an established Grazing District, with headquarters at Roswell. The bulk of the remainder occurs in a widely dispersed pattern in the watershed above Ft. Sumner. BLM's contribution to land and water conservation on the watershed consists principally of improved range management. However, in addition, it controls range fires, installs needed range improvements and carries on a limited amount of strictly soil and moisture conservation operations. All of the foregoing either

directly or indirectly improve watershed conditions and aid in flood control.

The Bureau of Reclamation has a soil and moisture conservation program in progress on its lands situated above Alamogordo Reservoir. Operations on this area are being coordinated with other land treatment measures and with plans for conservation work on privately owned land. The Bureau and the Carlsbad Irrigation District are testing methods of eradicating salt cedar from the sediment delta above Lake McMillan. This project includes studies of water saving in the area, of rate of sediment accumulation on the delta, and of the establishment of useful vegetation on the site. Results of the investigations will be used in estimating the effectiveness of a channel through the delta as a water saving measure, which is being considered by the Carlsbad Irrigation District.

The Bureau of Indian Affairs administers the Mescalero-Apache Indian Reservation, which has a land area of 294,000 acres in the Pecos River Watershed. Soil conservation and management practices being carried out on the Reservation are aiding in the reduction of floodwater and sediment damages.

The Fish and Wildlife Service directs rodent control work in the watershed in cooperation with appropriate state and local agencies. This work aids in improving the vegetative cover of the watershed.

The National Park Service administers 49,742 acres in the Carlsbad Caverns National Park. Management, revegetation, and structural measures are being carried out in the Park to perpetuate its scenic and recreational value and at the same time aids in flood control.

The current annual cost of the activities related to flood control which are directed by the Department of the Interior is estimated at $44,000.

Department of Agriculture.--The Forest Service administers 1,157,120 acres of Federal lands which form the headwaters of the Pecos River and its tributaries. These lands are a part of the Cibola, the Lincoln, and the Santa Fe National Forests. These national forests were established for the primary purpose of promoting watershed protection and their management has stressed the control of fire and destructive insects, and the regulation of livestock use and logging operations. Current activities also include range reseeding, road construction and maintenance, rodent control, construction of range fences and water developments. Recreation and other public uses of these lands are also supervised and regulated in the interest of watershed protection.

The Soil Conservation Service assists 25 soil conservation districts within the watershed in the planning and application of effective programs of soil and water conservation on private and state land. Certain measures and practices applied under district programs contribute to runoff retardation and soil erosion prevention. These include revegetation, contour furrowing, terracing, land leveling, crop residue management and structures such as diversions, dams, and dikes.

The Production and Marketing Administration makes direct aids available to farmers and ranchers who participate in the Agricultural Conservation Program to cover a portion of the cost of establishing approved conservation practices. These direct aids are helping with the installation of such measures as terracing, leveling, crop residue management, grass seeding, contour furrowing, construction of dams and dikes, all of which will reduce runoff and sediment from the land treated.

The Extension Service cooperates with the states, Texas and New Mexico, in performing its function of conservation education. A part of its educational program in rural areas throughout the watershed encourages and aids the application of practices and measures considered necessary to achieve flood control objectives.

The Farmers Home Administration furnishes financial and technical assistance to farmers and ranchers for the purpose of making improvements to their land which will conserve moisture and prevent erosion. Some of the measures which are carried out under this program contribute to flood control objectives.

The annual cost of the current activities of the Department of Agriculture in the watershed which are related to flood control is estimated at $413,600.

Municipalities and States.--Roswell, New Mexico and Pecos, Texas, have done some flood-protection work which reduces floodwater damage in these communities.

Twenty-five soil conservation districts have been organized under state law in the Pecos River Watershed. Landowners have developed a conservation program for the land within the districts and individual farm and ranch plans have been developed for many units. Many measures being applied are improving watershed conditions and contribute to flood control objectives.

RECOMMENDED PROGRAM

The program for runoff and waterflow retardation and soil erosion prevention herein recommended was developed in part from studies of sample areas which are representative of conditions throughout the watershed and in part through consultation with Federal, state

and local agencies having an interest in program objectives. Present conditions of the sample areas were examined in detail to determine floodwater and sediment damages and the kinds and amounts of practices and measures required for the most effective treatment to reduce the damages. The data obtained by the sampling procedure were applied to similar areas in the watershed as a basis for planning and recommending the proper combination of measures needed to accomplish flood control objectives.

The recommended program will substantially reduce floodwater and sediment damage and will improve the productivity of watershed lands. Watershed treatment measures are designed to improve vegetative cover which will improve soil characteristics and thereby increase the infiltration rate of rainfall into the soil, decrease surface runoff and control the water that runs off so that it does a minimum of damage on its way into the rivers and waterways. By retarding the rate of runoff and reducing the loss of soil by erosion, the program provides direct benefits in the reduction of damages caused by floodwaters and sediment. Measures carried out will be adapted wherever possible to improve wildlife resources in addition to serving their primary purposes.

The program is planned for completion during a period of 15 years. Watershed treatment measures will be installed, operated, and maintained on privately owned land by landowners and operators.

The recommended program consists of the following interrelated measures. The approximate number of each of these measures is shown in Table 2.

Stabilizing and sediment control structures.--Eroding gullies on range and forest land are the source of much of the sediment which damages downstream areas. Water quickly collects in the gullies during storms, and runoff and erosion are accelerated. Stabilizing structures will be installed in the active gullies to retard waterflow and prevent additional trenching. When the site is stabilized, vegetation will become established, thus completing the protection to the treated areas and furnishing more forage for livestock. It is estimated that 28,500 structures are needed to stabilize the areas where gullies are so critical that structural treatment is the only effective treatment. The less severely eroded areas will be stabilized by improved vegetation which will result from proper range management.

Range improvement.--The improvement of vegetative cover on 10 million acres of range and forest land is one of the most important phases of the recommended program. Changes which are expected in range and forest conditions will retard runoff, reduce rates of erosion and sediment production, and increase forage production. Most of the rehabilitation of watershed lands will be

accomplished by natural processes of revegetation under proper management. Critical areas will receive additional treatment. The range land that is depleted will be seeded to grass where favorable sites exist or are developed. Out of the total area within the watershed which needs reseeding, an estimated 182,000 acres are adapted to this treatment, including some cultivated land which is not suited to crop production. All seeded areas will be protected from grazing use until the grass is established.

Additional stockwater facilities are needed for better distribution of livestock. These facilities will permit the use of lands which can only be partially utilized until water is supplied and will alleviate concentration of use which occurs now in some localities. It is estimated that 113 units, consisting of wells and stock ponds, should be installed under the program recommended herein.

More fences are needed to obtain better distribution of livestock and thus aid in the improvement of vegetation. The amount of fencing needed to carry out the range management phase of the program is estimated at 685 miles. An area of approximately 378,125 acres in the watershed needs rodent control work to assist with the establishment of vegetative cover and to maintain it.

Road erosion control.--Accelerated runoff along roadsides which are not protected by vegetation or structures results in serious erosion and the development of gullies. Water disposal systems will be installed at suitable sites along the 2,225 miles of roads recommended for treatment. Other measures include retard structures and vegetative treatment.

Diversion dikes and ditches.--The installation of diversion structures on rangeland will divert runoff from channels to prevent rapid water concentration. Waterways which are being trenched or destroyed by head-cuts will be protected by a diversion dike and a system of ditches. Diversions will be installed above cultivated fields so that runoff can be carried away without damage to lands situated below the structures. It is estimated that 2,729 miles of diversion dikes and ditches need to be installed on the watershed. Approximately 415 miles are needed on range land, 1,014 miles on dry-farm land, and 1,300 miles to protect irrigated land.

Work roads.--To install measures in inaccessible areas of Federal lands, it will be necessary to construct approximately 30 miles of work roads.

Fire control.--More complete fire control facilities are recommended for 3,870,000 acres of range and forest land. The improvements proposed will prevent many fires and will speed up the suppression of fires when they occur, thus reducing the areas of grass and timberland destroyed. Fire control measures will contribute to the maintenance of good watershed conditions.

Land acquisition.--Federal acquisition of 60,000 acres of private lands within and adjacent to national forests which are critical flood and sediment source areas is recommended for watershed protection. Because of the poor quality of the land and its low financial returns, the lands involved are not properly managed for watershed protection and timber production. The acquisition of these lands will facilitate the application of conservation measures and proper management needed to bring about an improvement in cover conditions.

Terracing.--Terraces will be installed on dry-farm land to control runoff and reduce soil erosion on cultivated fields. Approximately 2,755 miles of terraces are recommended for the sloping lands that are the source of damaging runoff and sediment under present conditions.

Crop residue management.--The proper use of crop residue to provide conditions favorable for higher infiltration rates is recommended for 24,000 acres of non-irrigated cropland. The crop residue will retard runoff and reduce erosion on the areas treated.

Grass waterways.--Grass waterways will be developed in natural water courses to provide a disposal system for excess water from farm land. The grassed strips will extend through cultivated fields and beyond them to carry runoff into channels without damage. The amount of waterways needed to protect farm land is estimated at 2,050 acres.

Land leveling.--In the upper reaches of the Pecos River and its principal tributaries a large area of land is irrigated by diverting water from streams. Most of the land has considerable slope and soil erosion is a serious problem, making the irrigated fields an important source of sediment. It is recommended that 45,000 acres of the irrigated land be leveled to reduce erosion and improve water use.

Erosion control structures.--In order to control the application of irrigation water on the land recommended for leveling and to dispose of excess water, it is recommended that about 500 erosion control structures be installed.

Channel improvement.--It is recommended that about 2.5 miles of stream channel be improved by straightening, enlarging, and stabilizing, so that the flow of floodwater through high damage areas can be regulated.

Stream bank protection.--Approximately 45.5 miles of stream bank along the main stream and its important tributaries need to be protected to prevent bank cutting. The protective measures are designed to prevent the loss of highly developed irrigated land. The reduction in land losses will lower the rate at which reservoirs are filling with sediment.

Floodway systems.--Lands in tributary watersheds which have been developed for irrigation will be protected from overflow damage by floodway systems. Flood flows will be routed through the farm land by means of protective dikes to prevent overflow, and detention structures may be used to reduce the discharge. The floodway will protect crops from inundation and will prevent the deposition of infertile material on farm land. It is estimated that 14 miles of Floodways are needed to protect irrigated land in the tributary areas.

Detention structure.--In order to reduce floodwater damage to high value irrigated farmland along the Rio Bonita and the Rio Hondo, it is recommended that a detention structure be constructed on Salado Creek, a tributary to Rio Bonita. The proposed Capitan floodwater detention structure is designed to control floods of 100-year frequency from Salado Creek. An ungated outlet will gradually release water so that damage will be reduced downstream.

Salt cedar eradication and control.--The elimination of the salt cedar growth on the 14,000-acre delta area above Lake McMillan will salvage a substantial amount of water for beneficial use. It is recommended that the salt cedar be eradicated and that adapted grasses and other vegetation that will use less water than salt cedar be established on the area.

Other conservation practices and measures.--Additional soil and water conservation practices and measures will be applied as needed for a complete conservation program to meet the needs and capabilities of the land of the watershed.

The quantities of measures included in the recommended program are based on the total watershed needs less the estimated accomplishments under "going" programs over a 15-year period. The income of farm and woodland operators is expected to increase materially as the recommended program is installed and becomes effective. No major changes in the acreages of crops are anticipated.

Educational assistance.--Additional educational assistance is recommended to inform landowners and operators about the need of the recommended program, its purposes and objectives, and how the services available through action agencies can be secured to help establish the recommended program. Through the educational activities, land operators will be trained in the methods of installing land treatment measures which do not require technicians to design them and supervise their installation. Educational efforts will be intensified to develop widespread interest in the recommended program and to speed up the rate at which measures are applied.

Technical services.--Technical services will be furnished to help plan and apply an effective program of soil and water conservation on watershed lands.

Direct aids.--A portion of the cost of establishing certain land treatment measures on non-Federal lands will be provided in the form of direct aids.

Program evaluation.--Investigations and studies of program installations will be conducted in selected subwatersheds to determine their effectiveness and adequacy for runoff and waterflow retardation and soil erosion prevention. The evaluation of the program may indicate changes needed in the application of land treatment measures to make them more effective in reducing floodwater and sediment damages.

COST OF THE RECOMMENDED PROGRAM

The estimated cost of installing the recommended program in the Pecos River Watershed is $20,126,300. Of this cost, it is estimated that the Federal Government will expend $14,683,800; non-Federal public agencies, $388,000; and private interests $5,054,500. The total cost of the recommended program and the sharing of responsibility for installation are based on experience with land operators in the application of measures and practices similar to those herein recommended.

Federal participation will include educational assistance, technical services, materials, planting stock, special equipment, and direct aids where appropriate and needed to assist with the installation and maintenance of the recommended practices and measures.

The cost and the responsibility for the installation of any phase of the recommended program herein assigned to the Federal Government may be assumed by state governments or responsible local agencies or governments. State and local agencies will be urged to participate in the program to the fullest extent possible thus sharing the cost in proportion to the benefits that will accrue to them.

The estimated average annual cost of operating and maintaining the recommended program is estimated at $337,840. Of this amount, the Federal Government will expend $115,975; non-Federal public agencies, $47,730; and private interests, $174,135. The Federal Government will provide 1)maintenance of measures which it has installed, from the time of completion of such measures to the time of transfer to a local agency for operation; 2) operation and maintenance of measures installed on land owned and land acquired by the Federal Government; 3) one-half the cost of maintaining adequate fire control on non-federally owned woodland,

and 4) one-half the cost of educational assistance and one-half the cost of technical services on non-federally owned woodland. Non-Federal public agencies will bear one-half the cost of educational assistance and one-half the cost of technical services on non-federally owned woodland.

The estimated cost of installing the recommended program in the Pecos River Watershed is shown in Table 2.

Table 2

ESTIMATED COST OF INSTALLING THE RECOMMENDED PROGRAM IN THE PECOS RIVER WATERSHED

Item	Unit	Approximate Number	Cost (1948 Prices)
Stabilizing and Sediment Control Structures	each	28,500	6,665,000
Range Improvement			
a. Grass Seeding	acre	182,000	2,322,000
b. Stockwater facilities	each	113	527,000
c. Fencing	mile	685	585,000
d. Rodent Control	acre	378,125	174,000
Road Erosion Control	mile	2,225	291,000
Diversion Dikes and Ditches	mile	2,729	573,000
Work Roads	mile	30	13,500
Fire Control	acre	3,870,000	781,000
Land Acquisition	acre	60,000	394,000
Terracing	mile	2,755	517,000
Crop Residue Management	acre	24,000	55,000
Grass Waterways	acre	2,050	119,000
Land Leveling	acre	45,000	3,559,000
Erosion Control Structures	each	500	492,800
Channel Improvement	mile	2.5	173,000
Streambank protection	mile	45.5	1,107,000
Floodway Systems	mile	14	325,000
Detention Structures	each	1	403,000
Salt Cedar Eradication and Control	acre	14,000	1,050,000
TOTAL			20,126,300

The costs of technical services, educational assistance, program evaluation, and administration of direct aids are included and make up 22.8 percent of the total cost of the recommended program.

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BENEFITS FROM THE RECOMMENDED PROGRAM

The principal monetary benefits that will result from carrying out the recommended program are reductions in floodwater damage, reductions in sediment damages, increased forage, timber, and crop production, and an increased water supply.

Benefits from Reduction in Floodwater Damage.

The recommended program will reduce the damage caused by small floods which occur most frequently, by 90 percent. There will be a reduction in peak flows and damages caused by larger, infrequent floods, but the effect of the program will be less than in the case of the small flood. Most of the floodwater reduction benefits will accrue to agricultural interests in the highly developed irrigated areas in the Pecos River Watershed. Deposition of infertile material on cropland and loss of farm land by streambank erosion will be reduced by land treatment measures which will reduce flood peaks and by streambank stabilization work. Agricultural benefits account for about three-fourths of the floodwater reduction benefits. The remaining floodwater reduction benefits will accrue to urban areas, roads, railroads, and to public utilities. It is estimated that the recommended program, when properly installed and adequately maintained, will reduce floodwater damages about 50 percent.

Benefits from Reduction in Sedimentation.

The chief benefit which will result from a lower rate of sediment production on the watershed as a result of the recommended program will accrue to irrigation interests. Lower sedimentation rates in the storage reservoirs of irrigation companies will extend the useful life of the facilities and greater capacities will be available to carry over water supplies. The average annual damage to reservoirs by sediment is expected to be reduced by an estimated 23 percent.

Benefits from increased forage, timber, and crop production.

Increased forage production which will result from land treatment measures on range land makes up most of the conservation benefits of the program. The predominant use of watershed land is livestock grazing. It is estimated that forage production on 10 million acres of range land can be increased by 417,000 tons annually by proper range management and other recommended land treatment measures. Reseeding of depleted range land and abandoned crop land will increase forage production by an additional 55,000 tons annually. Measures recommended for farm land will conserve soil and moisture and will result in greater crop yields. The program of watershed management will increase timber production by a more adequate system of fire control.

Conservation benefits accruing to watershed lands as a result of the recommended program are estimated to be 90 percent of the total benefits.

The benefit which will result from the eradication of salt cedar is a saving of irrigation water estimated to be 12,000 ac.ft. annually.

Intangible benefits were not assigned a monetary value. Hence important benefits are not included in the table of benefits. Some of these are the prevention of loss of human life by reducing the destructiveness of flash floods which overtake occupied areas before they can be evacuated. A reduction in the frequency of flooding will prevent the development of unsanitary conditions which are hazards to health. Elimination of much of the inundation by small floods and a reduction in the depth of inundation by floods of greater magnitude will reduce the occurrence of costly detours or delays in transportation services, and interruption in business activities. Improvements of vegetative cover throughout the watershed which will hold and build soil will also provide food and cover for wildlife. These improvements will also increase the values of the watershed for recreational uses such as camping, picnicking, and hunting.

The estimated average annual benefits resulting from the recommended program for the Pecos River Watershed are shown in Table 3.

Table 3

ESTIMATED AVERAGE ANNUAL MONETARY BENEFIT FROM THE PROGRAM RECOMMENDED FOR THE PECOS RIVER WATERSHED

Source	Average Annual Benefit (1948 Prices)	
	Dollars	
Reduction of Floodwater Damage:		
Agricultural - Cropland, irrigation systems	221,800	
Nonagricultural - Urban and Public Utility	48,700	
Subtotal		270,500
Reduction of Sediment Damage:		
Reservoir Sedimentation	89,200	
Subtotal		89,200
Other Benefits:		
Increased Water Yield	189,000	
Conservation Benefits 1/	5,006,500	
Subtotal		5,195,500
TOTAL AVERAGE ANNUAL BENEFIT		5,555,200

1/ The benefit which accrues to the owners and operators of the land on which the recommended measures are installed.

COMPARISON OF BENEFITS AND COSTS

A comparison of the benefits anticipated to accrue from carrying out the recommended practices and measures with the probable costs thereof has been made by converting both benefit and cost estimates to average annual values.

Because prices will vary during the installation period, comparisons of the estimated average annual benefits and costs have been made on the basis of price and cost levels assumed to prevail under an intermediate level of employment. A $2\frac{1}{2}$ percent interest rate was used to convert total Federal and non-Federal public costs to an average annual equivalent cost, and a 4 percent interest rate was used to convert total private installation costs to an average annual equivalent cost. This was done in order that there might be a clearer understanding of probable benefits that will accrue from the recommended program and probable costs to be incurred in the installation of the program.

The benefit-cost ratio is 3.5 to 1.

The basis for the adjustments in determining this benefit-cost ratio is as follows:

Index of prices received by farmers 287 to 150 (1910-1914 = 100).

Index of prices paid by farmers 249 to 165 (1910-1914 = 100).

Index of construction cost of earthwork 159 to 122 (ICC index 1910-1914 = 100).

Index of other construction costs 461 to 325 (1913 = 100).

APPENDIX
SURVEY REPORT

PECOS RIVER WATERSHED

NEW MEXICO and TEXAS

PROGRAM FOR RUNOFF
AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U. S. DEPARTMENT OF AGRICULTURE

JULY 1950

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX - SURVEY REPORT

PECOS RIVER WATERSHED
New Mexico and Texas

Program for Runoff and Waterflow Retardation
and Soil Erosion Prevention

Pursuant to the Act approved June 22, 1936 (49 Stat. 1570
as amended and supplemented by the Act approved
June 28, 1938 (52 Stat. 1215)

July 1950

17340

REVIEW AND COMMENTS OF AGENCIES

OTHER THAN THOSE OF THE DEPARTMENT OF AGRICULTURE

AND OTHER INTERESTS

Pecos River Watershed Survey Report and Appendix

In accordance with policies and procedures adopted by the Federal Inter-Agency River Basin Committee, the report was sent to the following agencies for review and comments;

Agency	Address	Date of: Transmittal	Date of: Reply
Corps of Engineers	Dallas, Texas	8-15-50	9-15-50
	Albuquerque, N.M.	"	
Bureau of Reclamation	Amarillo, Texas	8-15-50	9-28-50
	Albuquerque, N.M.	"	
Fish & Wildlife Service	Albuquerque, N.M.	8-15-50	8-18-50
Bureau of Indian Affairs	Albuquerque, N.M.	8-15-50	9-15-50
Bureau of Land Management	Albuquerque, N.M.	8-15-50	9-15-50
Bureau of Mines	Denver, Colorado	8-15-50	9-5-50
Geological Survey	Santa Fe, N. Mex.	8-15-50	8-24-50
	Austin, Texas	9-5-50	9-25-50
National Park Service	Santa Fe, N. Mex.	8-15-50	8-31-50
Office of Field Service Department of Commerce	Denver, Colorado	8-11-50	8-17-50 1/
Weather Bureau	Ft. Worth, Texas	8-11-50	8-21-50
Coast and Geodedic Survey	Ft. Worth, Texas	8-15-50	9-1-50
Federal Power Commission	Ft. Worth, Texas	8-11-50	8-23-50

1/ Acknowledged receipt of report but has not provided formal comments.

Cont'd

Agency	Address	Date of: Transmittal	Date of: Reply
Pecos River Compact Commission	Santa Fe, N.M.	8-15-50	8-24-50 1/
New Mexico State Engineer	Santa Fe, N.M.	8-16-50	9-25-50
Texas Board of Water Engineers	Austin, Texas	8-28-50	9-6-50
Texas State Soil Conservation Board	Temple, Texas	8-25-50	8-31-50

1/ Acknowledged receipt of report but has not provided formal comments.

Copies of letters received from officials commenting on the report follow:

CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DIVISION ENGINEER
SOUTHWESTERN DIVISION

1114 Commerce Street
Dallas, Texas

15 September 1950

Regional Director
Soil Conservation Service
P. O. Box 1348
Albuquerque, New Mexico

Dear Sir:

Receipt is acknowledged of the revised draft of your survey report on the Pecos River, Texas and New Mexico, which you submitted for our review and comment with your letter dated 15 August 1950. It is noted that a copy of the report was also furnished the District Engineer, Corps of Engineers, Albuquerque, for review and comment. This office is now in receipt of the District Engineer's comments, which are as follows:

"2a. Text, page 11, 1st paragraph, 1st line. 'The Corps of Engineers is conducting a general flood control survey in the watershed. Recommendations contained herein have been correlated with the contemplated program of the Corps of Engineers in order to provide the most complete flood protection that is feasible.'

Comment. - In view of the foregoing statement, it is believed that the report of the Department of Agriculture should reflect the correlation with the contemplated program of the Corps of Engineers. However, with reference to table 10, following page 52, in the appendix, estimated future average annual flood damages listed for the area on Rio Hondo below Hondo Reservoir depart widely from the flood damages estimated for the same area by this District. Further, it is indicated that the contemplated program of the Corps of Engineers was not considered in determining future damages, since the area referred to would be in the protected area of the proposed Two Rivers flood control project. (It was estimated that the Two Rivers Reservoir would prevent most of the flood damage in this area.) Reference is also made to table 16, following page 77 of the appendix of the Department of Agriculture's report, in which benefits credited to the recommended program of the Department of Agriculture apparently include benefits derived from the protected area of the proposed Two Rivers Reservoir project recommended in the report prepared by this District.

These discrepancies between the reports are not fully understood, since the Department of Agriculture is cognizant of the plans under consideration by this District, and of the results of the flood damage survey in the area referred to above.

b. Appendix, page 29, paragraph 90, line 6. - The report shows a gage height of 22.5 feet which does not agree with the gage height of 21.5 feet published in Water Supply Paper No. 438.

c. Appendix, page 29, paragraph 91, line 14. - Discharge of 40,000 c.f.s. at Dayton, which is stated to be the peak discharge at Dayton, is shown in Water Supply Paper No. 408, as the mean daily flow. In the water supply paper it states that a discharge on 18 September was not determined, but probably exceeded the previous maximum of 50,300 second-feet.

d. Appendix, page 31, paragraph 93, line 6. - The peak discharge shown for Dayton and Carlsbad are listed as mean daily flows in Water Supply Paper No. 763.

e. Appendix, page 32, paragraph 95, line 15. - The discharge of 56,200 c.f.s. at Red Bluff is listed in Water Supply Paper No. 928, as 52,600 c.f.s.

f. Appendix, page 39, paragraph 112. - Operation of Alamogordo Reservoir from 1937 to survey of 1944, approximately seven years, shows an average annual sedimentation rate of 3,500 acre-feet with an average annual discharge of 300,900 acre-feet. The average annual flow for a 42-year period, from 1905 to 1946, is estimated to be about 191,000 acre-feet as shown in the Pecos River Compact. This is about 37 per cent lower than the flow during the period of sediment record. Thus, it seems for a long period the average sedimentation rate for Alamogordo Reservoir will be approximately 2,200 acre-feet per year. The annual depletion rate would then be 1.4 percent instead of 2.3 percent as shown in the table.

g. Appendix, page 41, paragraph 119. - It is stated that the estimated annual sediment rate of the Rio Hondo at Roswell is about 800 acre-feet. This is from 1,146 square miles of drainage area. In a letter from Robert V. Boyle, Acting Regional Director of the Soil Conservation Service at Albuquerque, New Mexico, dated 23 June 1950, it was stated that the average annual sediment rate at the Old Hondo Reservoir site was estimated by Dr. Eldon Thorp, Soil Conservation sedimentation specialist, as 500 acre-feet annually. The drainage area above

the old Hondo Reservoir is about 1,011 square miles. This letter verifies previous estimates made by Dr. Thorp in discussions held in connection with the preparation of the Corps of Engineers' Interim Report on Survey for Flood Control, Rio Hondo at Roswell, New Mexico. The letter, which was included as Exhibit 8 of Appendix VI to the Corps of Engineers' report, also states that the estimate of 500 acre-feet would appear in the Soil Conservation Service Survey Report on the Pecos basin. Based on the above, it appears that the Soil Conservation Service estimate of sedimentation has been revised upward considerably since 23 June 1950. This office has not estimated the rate of sediment flow on Rio Hondo at Roswell, but based on the estimated, 320 acre-feet annually for 1,084 square miles at the Two Rivers Reservoir site, the estimated annual rate for the 1,146 square miles could not exceed about 350 acre-feet.

h. Appendix, page 48, paragraph 144, line 8. - 'Floods in Salt Draw damaged railroads and urban property in Toyah in 1940. Enlargement of the protective dikes has largely eliminated this flood hazard.'

Comment. - Apparently the above is the only reference made to the flood problems on Salt Draw. Possibly the recent agricultural development on Salt Draw in the vicinity of Pecos, Texas, has been overlooked as a flood problem area. Investigations by the Albuquerque District indicate that this area is the principal flood problem area in the Texas portion of the Pecos River watershed. A preliminary flood damage survey shows justification for a flood control investigation, which will be reported on in the forthcoming survey report on the Pecos River, being prepared by this District.

i. The report of the Department of Agriculture does not specify the location of recommended improvements on Pecos River and major tributaries, nor does it give details on the extent and type of treatment. Therefore, this district will be seriously handicapped in evaluating effect of the proposed water flow retarding works on plans under consideration for the forthcoming flood control report on the Pecos River, unless these projects are more clearly defined.

"3. In addition to the report referred to above, the Department of Agriculture furnished a paper, Stream Bank Protection at Fort Sumner, New Mexico, Analysis of Feasibility, copies of which are inclosed. This paper outlines the procedure used in evaluating benefits for the prevention of bank caving at Fort Sumner. It further shows that a project for the prevention of bank caving is economically justified. Detailed comments on this paper are contained in the following paragraphs.

"4. Reference is made to the method of analysis used by the Soil Conservation Service in evaluating the economic losses resulting from stream bank erosion. These economic losses were estimated to be equal to the annual reduction in net farm income, capitalized at 4 per cent interest rate (Page 2, paragraph 2 of Soil Conservation Paper). This procedure in effect amounts to evaluating the land at $1,667 per acre (1948 value) and $815 per acre (normal value), since the values are substituted for acres of land in computing benefits in the second paragraph on page 6. These values are three to five times the current market value of the land of about $300 per acre, including improvements and water rights. By using these synthesized values as shown in table 4 on page 8, the Soil Conservation Service arrived at a total estimated benefit of $23,320 (1948 prices) and $11,530 (normal prices) which, when compared to annual charges indicate an economical ratio of benefits to cost of 2.02:1 (1948 prices) and 1.42:1 (normal prices). In contrast, by following the Corps of Engineers' practices, the average annual benefit derived from the market value of the land at $300 per acre would be $3,990. This benefit when compared to cost shows an unfavorable economic ratio of 0.35:1 based on the 1948 costs shown in the Soil Conservation report.

"5. The method of analysis used by the Soil Conservation Service would appear proper only if the following conditions were true:

a. That the rate of bank caving of cultivated land will continue for an infinite length of time at the rate used in the analysis.

b. That the caving of one acre of land now cultivated results in a loss for all time of the net value of the resource normally produced.

"6. With reference to condition 5a, it appears that sooner or later a status of equilibrium would be reached when the caving of cultivated land in the Fort Sumner District will cease or continue at a much reduced rate. With respect to condition 5b, it is pointed out that the production of crops in the Pecos Valley entails the use of both land and water. Bank caving results in only the loss of the land, and when consideration is given the fact that far more irrigable land is available than can be irrigated with available supply, it would appear that the loss of an acre of land alone does not necessarily mean the loss of the production heretofore realized from that acre because the water could be used elsewhere in the Pecos Valley to produce an equal yield."

This office is in general agreement with the comments of the District Engineer, but it appears from a review of his comments that it

should not be difficult to reconcile all of the major conflicts between our proposed reports. Accordingly, I will arrange for our District Engineer to confer with you, with a view to coordinating our reports in all essential particulars.

Sincerely yours,

/s/ Louis W. Prentiss

Louis W. Prentiss
Colonel, CE
Division Engineer

SEAL

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Region 5
Amarillo, Texas
Box 1609

September 28, 1950

Mr. Cyril Luker
Regional Director
Soil Conservation Service
Albuquerque, New Mexico

Dear Mr. Luker:

Reference is made to your letter dated August 15, 1950, under which you transmitted to this office for review and comments your revised flood control survey report for the Pecos River watershed, New Mexico and Texas dated July 1950. Reference is also made to the conference of representatives of your office and this office held in Amarillo on September 19, 1950 for the purpose of reconciling the viewpoints of our respective offices with respect to the pertinent material of mutual concern covered by the above-mentioned survey report. I am sure that the conference was mutually beneficial and it is my hope that it will lead to even closer cooperation between the staffs of our respective organizations.

In view of the exchange of information and viewpoints which was accomplished at the September 19 conference, I will limit my comments on your report to the following:

As a result of our conference it is recognized that your staff has made every effort within the limits of the available data to evaluate the runoff losses that necessarily would result from installation of the measures proposed in your program. Also, your program has been designed to minimize such losses insofar as is practicable and yet obtain the objectives of your program, which are improvement of the watershed conditions and productive capacity of the Pecos River Basin. However, lack of adequate prototype field data precludes not only the establishment of the water losses which would result from installation of the contemplated program but also measuring the benefits such as sediment control, etc., which would result therefrom and against which the costs and losses of your program must be equated to achieve a proper understanding of the value of your program.

Our conference established, and I believe it proper that your report appropriately explain, that the runoff losses to be anticipated would result almost entirely from securing improved

range practices with which this office is in complete accord and that the effect on runoff of the conservation measures proposed for the remaining 56,000 acres of concern to your report would be so negligible as not to be within the accuracy of your basin water supply studies. Consequently this office merely desires to urge again that appropriate action be taken to initiate a program under which adequate prototype data concerning the effect of watershed improvement measures for large river basins such as proposed by your Department may be obtained. I assure you this office will be glad to cooperate in any appropriate way not only in the planning and carrying out of such a program but also in the seeking of necessary funds therefor. We believe that, as the costs of the nation-wide watershed improvement program of your Department would likely amount to several billion dollars, the expenditure of a few hundred thousand dollars to permit evaluation of the effect and benefits of such program is amply justified.

It is of concern to me that your report justifies the incurrence of the estimated water losses that will result from your program at least partially by stating that such losses will be largely off-set through water salvage measures to be effected in the McMillan Reservoir delta area. As you are aware, the Pecos River Compact includes provisions concerning the apportionment between the States of Texas and New Mexico of any waters salvaged in the basin, and I recognize that the real responsibility for decision as to the use to be made of New Mexico's share of any waters so salvaged appropriately must rest with that State. However, I feel very strongly the principle should be recognized that first consideration in the use of any salvaged waters should be given to established projects, such as the Fort Sumner and Carlsbad Irrigation Projects, and assignment of any waters surplus to the needs of such projects should be made on the basis of the dominant basin needs for such waters and the relative benefits to be derived therefrom. I believe such principle could be recognized in your report without undue conflict with your plan, as the water salvage measures proposed in our Project Planning Report No. 5-15.13-0 dated August 1950, on which you furnished comments under letter dated August 22, 1950, and to which your proposed water salvage measures would be supplementary, would make available the additional flows desirable to supplement the supplies of the existing projects which are the concern of this office.

This office has reviewed in detail the comments of your office with respect to the sediment inflow evaluations for the Alamogordo, McMillan, and Red Bluff Reservoirs. This review confirms our belief that the evaluations made by our staff and which are the basis of the findings presented in our above-mentioned Project Planning Report No. 5-15.13-0, are more representative of the conditions likely to prevail than those presented in the present draft

of your report. Therefore, in view of our responsibility for reservoirs of the Carlsbad Project and in the interest of coordinating our presentations wherever appropriate, I assure you of the willingness of this office to be credited with the sediment inflow evaluations should your office care to present in your report the recorded inflows to date and use our forecasts of probable future inflows.

Your report very appropriately states the division of responsibility for carrying out the program which your Department envisions, and on this I am sure the Department of the Interior will desire to comment. However, I would suggest that, in order to permit a clearer understanding of your proposals, your report should also indicate the division of responsibilities contemplated with respect to the preparation of work plans, seeking of funds and other program matters essential to initiating and carrying out of the program.

Very truly yours,

/s/ H. E. Robbins

H. E. Robbins
Regional Director

SEAL

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Office of the Regional Director
Albuquerque, New Mexico
P. O. Box 1306

August 18, 1950

Mr. Cyril Luker, Regional Director
Soil Conservation Service
Department of Agriculture
Post Office Box 1348
Albuquerque, New Mexico

Dear Mr. Luker:

Reference is made to your letter dated August 15, 1950, which forwarded, for our review and comments, a draft copy of your Survey Report, Pecos River Watershed, New Mexico and Texas, dated July 1950.

Insofar as Fish and Wildlife Service interests are concerned, we are pleased to endorse this report. We feel confident that the measures recommended in it will materially benefit fish and wildlife resources in the basin. While the report does not bring it out, on a number of occasions personnel from our respective offices discussed the recommended program for the purpose of considering the needs of fish and wildlife resources in the basins, and how when the recommended measures are installed they might produce increased fish and wildlife benefits. We will welcome an opportunity to consult with you again at that time.

Your consideration in furnishing the report for our comments is sincerely appreciated. When they are available, we would like to have an additional copy of the report for our reference files.

Very truly yours,

/s/ John C. Gatlin

John C. Gatlin,
Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
Office of Indian Affairs
Field Service

Albuquerque Area Office
Albuquerque, New Mexico
September 15, 1950

Mr. Cyril J. Luker, Regional Director
Soil Conservation Service
Albuquerque, New Mexico

Attention: Mr. Robert V. Boyle

Dear Sir:

We received the revised draft of the flood survey report for the Pecos River watershed in New Mexico and Texas, with your covering letter of August 15th.

This report has been reviewed by members of my staff and a very favorable comment has been made. The report seems to be very completely and accurately prepared. There is one point which we would like to further clarify, namely that Indian land is not in the strict sense Federally owned. The Federal government does, as you are aware, exercise supervision over Indian lands. This responsibility rests with the Indian Service. In some instances, as in the case of the Pueblo grants, title is held by the Indians from the King of Spain. Patents have been issued by the United States Government on lands of this patent category.

In other cases the Indian land is held in trust for particular tribes. It is the policy of the Indian Bureau to enlist the aid and support of the Indian tribal representatives in any matter affecting land of that particular tribe.

We do not understand from your August 15th letter whether we are to return or keep the copy of the report submitted to us. We would like to keep this if you have no objection. However, if you would like it returned please so inform us and we will immediately return it. We wish to thank you for an opportunity to review this report and assure you our full cooperation in any way we are able to contribute.

Sincerely yours,

/s/ Eric T. Hagberg

Eric T. Hagberg
Area Director

SEAL

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

P. O. Box 1695
Albuquerque, New Mexico

September 15, 1950

Mr. Cyril Luker
Regional Director
Soil Conservation Service
Albuquerque, New Mexico

Dear Mr. Luker:

In his letter of August 15, Acting Regional Director Robert V. Boyle requested our comments on the "Revised Draft of the Flood Survey Report for the Pecos River Watershed in New Mexico and Texas," that accompanied that letter.

I think the authors of the draft are to be complimented on the soundness of their approach, the clarity of their thinking and the terse yet complete expression of that thinking. Particularly as regards their handling of the "Method of Estimated Sediment Damage to Reservoirs" do I believe they have made a notable contribution to the thinking of many of us.

Over the telephone today I told Mr. Ray McDaniel that we believe the two statements (reference page 11 of the Survey Report and page 20 of the Appendix) can be improved upon. Unless you have serious objection, I should like the enclosed statement to appear in both locations. It states in small compass everything that we have to say at this time. The only difference in its appearance in the Appendix from that in the Report would be that the heading should read: "Department of the Interior, Bureau of Land Management.—"

Sincerely yours,

/s/ E. R. Smith

E. R. Smith
Regional Administrator

Enclosure

Enclosure to letter from
Bureau of Land Management
dated September 15, 1950

Department of the Interior.--The Bureau of Land Management administers more than 2 million acres of public domain grazing land within the Pecos River watershed in New Mexico, pursuant to the Taylor Grazing Act of 1934. (There exists no public domain in the State of Texas.) Most of this public domain lies within an established Grazing District, headquarters Roswell. The bulk of the remainder occurs in widely dispersed pattern in the watershed above Ft. Sumner. BLM's contribution to land and water conservation on the watershed consists principally of improved range management. However, in addition, it controls range fires, installs needed range improvements and carries on a limited amount of strictly soil and moisture conservation operations. (The two last-mentioned items have been financed at an annual cost of approximately $17,000 of Government funds.) All of the foregoing either directly or indirectly improve watershed conditions and aid in flood control.

SEAL

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

224 New Customhouse
Denver 2, Colorado

September 5, 1950

Mr. Robert V. Boyle
Acting Regional Director
Soil Conservation Service
U. S. Department of Agriculture
Albuquerque, New Mexico

My dear Mr. Boyle:

I have had the survey report "Pecos River Watershed, New Mexico and Texas" reviewed. It has been determined that the proposals have no direct bearing on the mineral resources of the basin and the Bureau of Mines has no objections or comments to make.

Sincerely yours,

/s/ J. H. East, Jr.

J. H. East, Jr.
Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

P. O. Box 277
Santa Fe, New Mexico

August 24, 1950

Mr. Cyril Luker, Regional Director
U. S. Soil Conservation Service
Box 1348
Albuquerque, New Mexico

Dear Mr. Luker:

As District Engineer of the Geological Survey, I received one of the Soil Conservation Service reports on its proposed program on the Pecos River drainage. This report was read, and returned yesterday to Harold Elmendorf with my comments given to him verbally.

The office still has the second copy of the report which was sent to me as Commissioner representing the United States on the Pecos River Commission.

Very truly yours,

/s/ Berkeley Johnson

Berkeley Johnson
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SOUTHWEST FIELD COMMITTEE - REGION 6
302 West 15th Street
Austin 14, Texas

September 25, 1950

Mr. Harold B. Elmendorf, Chief
Regional Water Conservation Division
P. O. Box 1348
Albuquerque, New Mexico

Dear Harold:

Please excuse my delayed reply to your letter of September 5, 1950, concerning my review of your agency's report "Pecos River Watershed, New Mexico and Texas — July 1950":

I have been away from Austin a greater part of the time since receiving your letter in connection with work relating to the Arkansas-White and Red River Inter-Agency Basin Committee, and for that reason I have not had an opportunity to study the report. Mr. Fox is correct in that I am the U. S. Geological Survey contact official to which such reports should be submitted for field review by the Geological Survey in the Interior Department's Southwest Region 6 (extends from the Continental Divide on the west to the main stem of the Mississippi on the East and includes all of the Arkansas Basin on the north and coastal streams southward to the Gulf of Mexico). Your letter advises that Berkeley Johnson, C. V. Theis, and John Hem of the U. S. Geological Survey have reviewed the report. It is my feeling that their comments will be sufficient for the U. S. Geological Survey's field review.

For your information I might advise, however, that the U. S. Geological Survey's principal concern in reports of this nature is to make sure that your agency is supplied with available basic data that may be of value to your agency in the proposed investigation. The Geological Survey is also concerned with your needs for additional basic data and in this connection it desires to cooperate in every way possible to secure such information. Basic data relating to water resources, topographic mapping and geology may be obtained from the following Geological Survey officials:

Surface Water Resources:

New Mexico - Mr. Berkeley Johnson, District Engineer
P. O. Box 277, Santa Fe, New Mexico

Texas. - Mr. C. E. Ellsworth, District Engineer
302 West 15th Street, Austin 14, Texas

Geology: Mr. E. B. Eckel, Chief, Engineering Geology Branch, Denver Federal Center, Denver Colo.

Topography:

New Mexico - Mr. R. O. Davis, Regional Engineer
Denver Federal Center, Denver, Colorado

Texas - Mr. Daniel Kennedy, Regional Engineer
P. O. Box 133, Rolla, Missouri

It is unfortunate that the Geological Survey does not have a substantial amount of basic data regarding the variations of runoff from small areas. Our long range program anticipated the establishment of a large number of stream flow stations for recording runoff from typical small streams in various sections of the Interior Department's Southwest Region 6. Current appropriations, however, will permit only the establishment of a few such stations during the 1951 fiscal year. At this time I do not know whether any of these will be established in the Pecos River Basin during 1951.

Very truly yours,

/s/ Trigg Twichell

Trigg Twichell
Geological Survey Representative

cc - Mr. Berkeley Johnson
Mr. Cyril Luker, Albuquerque, New Mexico

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

Region Three
Santa Fe, New Mexico

August 31, 1950

Regional Director, Region Six
Soil Conservation Service
P. O. Box 1348
Albuquerque, New Mexico

Dear Sir:

The U. S. Department of Agriculture Survey Report, Pecos River Watershed, New Mexico and Texas, transmitted with Mr. Robert V. Boyle's letter of August 15, has been reviewed by members of my staff.

The report is comprehensive in scope and deals with a situation which has long been recognized as one of vital concern to the Southwest.

In commenting on your report, I note that no mention of the National Park Service is made under "Activities Related to Flood Control, Department of the Interior," page 11 of the report. Carlsbad Caverns National Park, an area of 49,742 acres, is located in Eddy County within the Pecos River Watershed. This land is considered to be moderately eroded, which is in agreement with your map No. 5 of the Appendix. We are now carrying out management practices to aid in the reduction of floodwater and sediment damage. Other soil conservation measures planned for this area are range re-seeding and sediment control structures estimated to cost $6,500. Possibly it would be desirable to show the National Park on your maps as has been done for other Federal areas, such as National Forests.

We would like to suggest the following revision of paragraph 59, page 17, as being somewhat more comprehensive, and, in certain respects, more accurate than the one in your report:

59. Recreational use. There are many recreational attractions in the watershed. These include notably the high, scenic mountain areas near the headwaters and along the western flanks of the basin, especially in New Mexico. Many camp sites and recreational areas have been developed in the national forests. Carlsbad Caverns National Park,

administered by the National Park Service, is in the mid-basin in New Mexico, and there are two state parks, Bottomless Lakes near Roswell, New Mexico, and Balmorhea in Texas. Considerable recreational use is made of the Alamogordo, Avalon, and Red Bluff reservoirs. The region is rich in historic interest, with remains of several frontier Army posts, and there is significant archeological evidence of long prehistoric occupation and use.

The opportunity to review your report has been appreciated.

Very truly yours,

/s/ M. R. Tillotson

M. R. Tillotson
Regional Director

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
Area Hydrologic Engineer

501 U. S. Court House
Fort Worth 2, Texas
August 21, 1950

Regional Director
Department of Agriculture
Soil Conservation Service
Albuquerque, New Mexico

Dear Sir:

We have reviewed the Survey Report of the Pecos River watershed which you forwarded to us under your letter of August 11, 1950. The Weather Bureau has no comment to make concerning the report. Please furnish a copy of the final report to Weather Bureau Office, Washington, D. C.; also one copy to this office.

Very truly yours,

/s/ R. J. MacConnell

R. J. MacConnell
Acting Area Hydrologic Engineer

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY

311 U. S. Court House
Fort Worth, Texas

1 September 1950

To: Regional Director
U. S. Soil Conservation Service
Albuquerque, New Mexico

Subject: Survey Report, Pecos River Watershed
U. S. Department of Agriculture - July 1950

I have read with interest the report on the Pecos River Watershed submitted to me and have no comment to make.

In connection with this report, however, we would like to call your attention to our principal interest in river basin development projects. The U. S. Coast and Geodetic Survey desires to maintain close contact with agencies concerned with river basin development, to the end that horizontal and vertical control survey data are available for surveying and mapping projects necessary in studies of development of these river basins. A requisite for investigation of terrain covering areas of any extent is basic horizontal and vertical control survey data, so that surveys and maps are coordinated on a common datum.

/s/ Benjamin H. Rigg

Benjamin H. Rigg
Captain, U.S.C. & G.S.
Officer in Charge

FEDERAL POWER COMMISSION
REGIONAL OFFICE

412 Neil P. Anderson Building
Fort Worth 2, Texas

August 23, 1950

Mr. Robert V. Boyle
Acting Regional Director
U. S. Department of Agriculture
Soil Conservation Service
Albuquerque, New Mexico

Subject: Survey Report - Pecos River Watershed
New Mexico and Texas, dated July 1950,
United States Department of Agriculture

Dear Mr. Boyle:

This is in reply to your letter of August 11, 1950, which transmitted the subject report and invited our comments. A commentary statement based upon a review of the subject report is submitted herein.

The authority for the subject report is submitted under the provisions of the Act approved June 22, 1936 (49 Stat. 1570) as amended and supplemented by the Act approved June 28, 1938 (52 Stat. 1215).

The purpose and scope of the report is to outline a program of runoff and water-flow retardation and soil erosion prevention for the Pecos River watershed in New Mexico and Texas, together with recommendations for installing and maintaining the program, and a cost and benefit analysis. The program covers a large portion of the 33,200 square miles of the Pecos River Basin.

Based upon 1948 prices, the recommended program would cost $20,126,300 for installation over a period of 15 years, and of this sum $15,676,900 would be federal funds and $4,449,400 non-federal funds. The annual operating and maintenance cost is estimated at $337,840, and the installation cost is $566,853, making the total annual costs amount to $904,693.

The average annual benefits for the recommended plan amount to $5,595,200. The structural phase of the program would be accomplished in 15 years, but the land improvement phase would continue for an additional 15-year period.

The Department of Agriculture's Survey Report on the Pecos River watershed, together with supplementary information and data, have been reviewed by the staff of the Federal Power Commission, Fort Worth Regional Office, Fort Worth, Texas.

The proposed program is essentially one of runoff and water-flow retardation, and soil erosion prevention, with the object of reducing flood and sediment damage and to conserve water. The report does not include or affect the development of hydroelectric power, except to the extent that some of the salvaged water would enter Red Bluff Reservoir for use in Texas as required under the Pecos River Compact. The salvaged water arriving at Red Bluff may add somewhat to the energy output at that power plant.

The staff recognizes the need for improved water conservation measures in the Pecos River Basin, based on a long range plan to overcome the rapid storage depletion.

In view of these considerations, it is the opinion of the staff of the Commission that the effect of the Department's watershed program upon the magnitude and annual value of the hydro-electric power potentialities of the Pecos River is insignificant as compared to the other benefits which would be derived from the recommended plan of improvement.

This office appreciates this opportunity for cooperative examination of the subject report. The report and its appendices have been retained for our files.

Very truly yours,

/s/ Wilbur F. Fairlamb

Wilbur F. Fairlamb
Regional Engineer

STATE OF NEW MEXICO
(SEAL)

OFFICE OF
STATE ENGINEER
Santa Fe
September 25, 1950

Mr. Cyril Luker
Regional Director
Soil Conservation Service
U. S. Department of Agriculture
Albuquerque, New Mexico

Dear Mr. Luker:

In compliance with your request to Mr. Berkeley Johnson, Chairman of the Pecos River Commission for review by the members of the Commission of the survey report, Pecos River Watershed - New Mexico and Texas, dated July, 1950, Mr. Johnson furnished this office with a copy of that report for review. We have studied the report, and find nothing at this time upon which we care to make comments or suggestions.

As you know, we have followed the preparation of this report for some time, and we feel that it has been very well prepared and evidences a great deal of careful study and work on the part of your staff.

Very truly yours,

/s/ John H. Bliss

John H. Bliss
State Engineer

JHB/jp

BOARD OF WATER ENGINEERS
STATE OF TEXAS
Austin

September 6, 1950

Mr. Paul H. Walser
State Conservationist
P. O. Box 417
Temple, Texas

Dear Mr. Walser:

Reference is made to your letter of August 28, 1950, concerning the revised preliminary draft of the USDA Survey Report, Pecos River watershed, New Mexico and Texas, which outlines a program for runoff and waterflow retardation and soil erosion prevention.

The program embraces a large and important area in the State, and the need of a program for prevention of soil erosion and flood control is certainly realized, and it is hoped such a program may eventually be authorized. The saving of water by elimination of salt cedars is considered also to be a much needed project.

As to eradication of salt cedars on the Pecos River watershed, it is believed the program should include also eradication of the salt cedars around the Red Bluff Reservoir, and at other points along the river where their growth is increasing. Salt cedar growth has become a serious problem in Texas as well as New Mexico.

Comments cannot be made on the cost or adequacy of reservoirs, floodway systems, channel improvements, or other items until tentative plans for their construction have been received. In general, it is hoped that any reservoirs to be constructed can be located to provide storage to meet the needs for conservation as well as for the proposed project. It is assumed that this Board will have an opportunity to examine and comment on individual plans for all the hydraulic structures to be located on the various streams in Texas.

Provided the proposed construction will not interpose any difficulty to the delivery of water to the Red Bluff Reservoir within the purview of the Pecos River Compact, the Board of Water Engineers concurs in your recommendation for installation of a program of runoff and water flow retardation and soil erosion prevention in the Pecos River watershed in New Mexico and Texas.

/s/ H. A. Beckwith

/s/ A. P. Rollins

BOARD OF WATER ENGINEERS,
STATE OF TEXAS

TEXAS STATE SOIL CONSERVATION BOARD
Temple

August 31, 1950

Mr. Paul H. Walser, State Conservationist
Soil Conservation Service
P. O. Box 417
Temple, Texas

Dear Mr. Walser:

We have examined with much interest the revised draft of the U.S.D.A. Flood Control Survey Report on the Pecos River Watershed in New Mexico and Texas as prepared by your Albuquerque regional office.

I do not feel that we are qualified to comment extensively on this report as we do not have a registered engineer in our department. As a layman, I do have some first hand knowledge of conditions in the area gained by on the ground observation.

The findings in this report seem to fully justify the procedures and expenditures recommended. The division and sharing of the expense incidental to the accomplishment seems to be well founded. There can be no question as to the need for action in this particular area.

Yours very sincerely,

/s/ V. C. Marshall

Executive Director

APPENDIX CONTENTS

Page

INTRODUCTION

1. Purpose and scope.—The appendix supplements the survey report for the Pecos River Watershed and outlines in detail a program of watershed treatment measures for run-off and waterflow retardation and soil erosion prevention in the interest of flood control. It describes watershed conditions and flood problems; methods and procedures used in estimating flood damage; program recommendations, appraisals, and costs.

GENERAL DESCRIPTION OF WATERSHED

2. Location and size.—The Pecos River Watershed heads above Las Vegas in the mountains of north central New Mexico and extends southward across western Texas to the Rio Grande (map 1). The watershed embraces about 44,500 square miles, of which 25,450 are in New Mexico and 19,050 are in Texas. This area includes about 11,300 square miles of inland drainage from which no surface run-off ever reaches the Pecos River drainage system. A major portion of the closed basin lies east of the river in the central portion of the watershed. For the purpose of this report only the direct contributing area, or approximately 33,200 square miles, is considered. The watershed is approximately 525 miles long, and the width varies from about 30 miles on either end to 100 miles in the central (widest) part.

28,480.000

3. Physiography.—The Pecos River Basin comprises the southwestern portion of the Great Plains province. It is bordered on the north by the Sangre de Cristo Range, on the west by foothills and Jicarilla, Sierra Blanca, Sacramento, Guadalupe, Delaware, and Davis Mountains, and on the east by low foothills and the "Staked Plains."

4. The topographic features range from the narrow, V-section mountainous valleys through rugged conyons and dissected plains to gently sloping and almost level surfaces. Along the middle reach, thick alluvial deposits floor the valley for many miles. Major tributary drainages, including Cienega del Macho, Rio Hondo, Rio Penasco, Toyah and Limpia Creeks, head in the steep mountains which fringe the western edge of the watershed. These drainages cut across the valley floor to enter the Pecos at right angles to its direction of flow. In its lower course, the river cuts across the Edwards Plateau for approximately one hundred miles. This reach, to its junction with the Rio Grande, occupies a canyon of moderate to strong relief trenched in the limestone of a young plateau.

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5. Closed basin areas.--One large continuous tract east of the river in the central portion of the watershed and several small tracts in the north central portion make up the 11,300 square miles in closed basins (map 1). Run-off from these areas finds its way into scattered lakes and sinkholes. Some surface water reaches underground channels and reappears as springs along the Pecos River.

6. Area considered by survey.--Only the direct drainage portion of the watershed (approximately 33,200 sq. mi.) was considered in conducting the survey since flood and sediment damages are of little consequence in the closed basin areas.

PHYSICAL FEATURES OF WATERSHED

7. General.--The watershed is steep and mountainous on the northern and western edges, gently sloping to hilly in the central portion between the mountains and the high plains, gently undulating east of the river, and gently sloping to rolling south of Girvin, Texas. Streams dissect every part of the watershed except the closed basin areas and are deeply entrenched in the northern and southern sections. A large, nearly level to gently sloping alluvial plain approximately 200 miles long and 10 to 30 miles wide is a distinguishing feature of the middle basin area. Elevations range from slightly less than 1,000 feet at the confluence of the river with the Rio Grande to over 13,000 feet in the northern mountains.

8. Climate.--The climate of the Pecos River Basin is temperate and continental in type, with cool winters and warm summers. Rainfall is light to moderate, relative humidity low, and sunshine abundant. Climatic conditions vary considerably and are due to geographical location, differences in elevation, and topography. Annual precipitation ranges from 10 to 12 inches in the low central plains area to as much as 30 inches in the high mountains. The Edwards Plateau and the high plains area on the south and eastern part of the watershed receive 16 to 20 inches of moisture. This area is nearest to the Gulf of Mexico, which is the source of most rainfall. Table 1 shows the average monthly and annual precipitation for selected stations in the Pecos River watershed and vicinity.

9. Approximately 75 to 80 percent of the annual precipitation comes during May through October, the growing season. Periods of prolonged drought are not uncommon, and many stations have recorded less than four inches

Table 1.—AVERAGE MONTHLY AND ANNUAL PRECIPITATION
Pecos Watershed and Vicinity - New Mexico and Texas

Station	County	Years of record	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
NEW MEXICO																
Arabela (near)	Lincoln	6	8,700	0.97	0.40	0.92	1.13	1.16	2.56	2.75	4.59	3.49	1.81	1.11	0.40	21.75
Artesia	Eddy	23	3,350	0.29	0.54	0.58	1.06	0.98	1.34	2.21	1.42	1.45	1.42	0.86	0.53	12.48
Boaz	Chaves	22	4,154	0.23	0.32	0.65	0.96	1.28	1.62	1.96	2.17	1.92	1.42	0.46	0.43	13.42
Capitan	Lincoln	21	6,348	0.59	0.89	0.80	0.83	1.07	1.52	3.61	3.09	1.87	0.95	0.47	0.79	16.28
Carlsbad	Eddy	35	3,120	0.32	0.35	0.54	0.77	0.78	1.79	2.39	1.88	1.71	1.41	0.57	0.54	13.05
Carson Seep R.S.	Eddy	16	6,500	0.67	0.57	0.86	1.12	1.41	1.53	3.51	3.30	2.69	1.81	0.88	0.85	19.00
Cloudcroft	Otero	28	8,650	1.49	1.46	1.39	0.79	0.94	1.47	4.54	4.76	2.72	1.64	1.30	1.37	23.77
Clovis	Curry	20	4,282	.23	.46	.74	1.61	1.98	2.89	2.68	2.97	2.21	1.81	.45	.56	18.59
Corona	Lincoln	21	6,666	.56	.71	.86	.83	.96	1.31	2.55	2.38	1.15	1.04	.45	.79	13.59
Cuervo	Guadalupe	21	4,849	.22	.48	.66	.99	1.51	1.43	1.98	1.93	1.41	1.38	.51	.63	13.11
Doretta	San Miguel	12	6,381	.64	.64	1.34	1.07	1.89	1.14	3.27	2.59	1.90	1.23	.43	.55	16.89
Duran	Torrance	22	6,272	.41	.62	.80	.92	1.30	1.46	2.64	2.55	1.36	.97	.48	.65	14.14
Elida	Roosevelt	14	4,345	0.20	0.28	0.61	1.26	1.87	2.38	2.19	2.28	1.96	1.34	0.43	0.51	15.07
Elk (near)	Chaves	19	5,350	0.41	0.39	0.46	0.64	1.09	1.45	4.71	3.05	2.28	1.84	0.80	0.58	17.07
Ft. Stanton	Lincoln	32	6,231	0.50	0.61	0.76	0.68	0.90	1.51	3.21	3.30	2.03	1.21	0.87	0.74	16.12
Ft. Summer	DeBaca	20	4,028	.37	.55	.88	.97	1.49	1.82	2.42	2.55	1.33	1.46	.78	.89	15.51
Ft. Union	Mora	22	6,885	.46	.49	.52	.89	1.63	2.33	3.72	3.67	2.03	1.11	.62	.54	18.01
Gallinas Pl.S	San Miguel	22	7,500	.66	1.31	1.56	1.75	2.31	2.50	5.56	4.36	2.01	1.61	.86	.90	25.39
Gallinas R.S.	Lincoln	20	6,636	.64	.65	.86	.87	1.12	1.08	2.66	2.18	1.36	1.10	.47	.84	13.83
Harvey's U.R.	San Miguel	15	9,400	1.51	1.84	2.37	2.52	2.41	3.43	5.96	8.10	2.16	2.49	1.10	1.54	33.43
Hope	Eddy	15	4,000	0.39	0.60	0.86	0.45	1.47	1.78	1.95	1.52	2.10	1.18	0.49	0.64	13.43
Lagunita	DeBaca	19	4,500	.39	.50	.68	1.16	1.13	1.66	2.15	2.17	1.73	1.31	.74	.72	14.34
Lake Avalon	Eddy	16	3,200	0.25	0.27	0.53	0.88	1.01	1.38	1.55	1.75	1.66	1.41	0.40	0.57	11.64
Las Vegas	San Miguel	37	6,400	.42	.77	.72	1.14	1.82	1.90	3.68	3.19	1.87	1.11	.68	.64	17.94
Loving	Eddy	12	3,045	0.28	0.36	0.42	0.69	1.26	1.12	1.46	1.97	1.47	1.52	0.54	0.46	11.55
Mayhill R.S.	Otero	14	6,400	0.52	0.51	0.66	0.52	1.43	1.57	3.93	4.10	2.49	1.85	0.77	0.55	19.03
Melrose	Curry	19	4,400	.32	.42	.86	1.52	1.57	2.27	2.26	2.69	2.09	1.44	.66	.64	16.74
Mineral Hill	San Miguel	18	7,050	.70	.99	.98	2.03	1.33	2.42	4.21	3.52	1.72	1.53	.88	.80	21.11
Montoya	Quay	22	4,335	.19	.47	.62	1.11	1.48	1.66	1.83	2.36	1.22	1.38	.61	.88	13.61
Nogal	Lincoln	12	8,000	1.85	1.11	1.35	1.45	1.20	1.86	4.66	4.12	2.20	1.42	0.98	1.61	23.81
Onava	San Miguel	21	6,700	.32	.70	.76	1.05	1.69	1.90	3.07	3.38	1.44	1.16	.40	.53	16.40
Palma	Torrance	15	7,000	.45	.62	.92	.79	.76	.86	1.93	1.51	.93	.94	.57	.72	11.00
Park Springs	San Miguel	14	5,100	.47	.61	.58	.98	1.59	1.84	3.01	2.12	1.85	1.02	.77	.73	15.57
Pastura	Guadalupe	20	5,285	.27	.53	.52	.83	1.30	1.45	1.96	2.44	1.64	1.26	.35	.58	13.13
Pecos R.S.	San Miguel	10	6,900	.69	.75	1.13	1.24	1.77	1.01	2.91	2.52	1.88	1.32	.49	.59	16.30
Portales	Roosevelt	21	4,004	.21	.42	.86	1.50	2.11	2.39	2.53	2.65	2.18	1.41	.67	.72	17.65
Richland (near)	Roosevelt	17	4,000	0.27	0.26	0.59	1.10	1.28	1.98	2.15	2.04	2.08	1.35	0.60	0.52	14.20
Roswell	Chaves	37	3,602	0.49	0.56	0.73	0.87	1.11	1.75	2.25	2.16	2.02	1.46	0.84	0.64	14.88
Santa Rosa	Guadalupe	21	4,624	.38	.53	.58	.80	1.63	1.61	2.38	2.65	1.40	1.32	.44	.86	14.38
Torrance	Torrance	17	6,433	.46	.59	.59	.67	.67	1.25	2.77	2.43	1.52	.86	.29	.79	12.89
Trementina	San Miguel	20	5,000	.29	.49	.67	1.38	2.09	1.92	2.12	2.41	1.51	1.50	.66	.64	15.68
Valmora	Mora	11	6,200	.34	.63	1.08	1.01	2.29	1.97	3.47	3.28	1.75	1.15	.51	.46	17.94
Vaughn	Guadalupe	21	5,930	.34	.49	.53	.84	1.53	1.32	2.49	1.76	1.85	1.29	.37	.64	13.45
Weed R.S.	Otero	11	7,200	0.91	0.74	1.03	0.60	1.64	1.88	4.61	4.34	2.19	1.78	0.82	0.83	21.27
White Tail	Otero	14	7,000	0.93	0.65	1.26	0.83	1.52	1.57	5.05	4.25	2.19	1.61	0.87	1.02	21.76
Winsor's Ranch	San Miguel	28	8,000	1.13	1.60	1.72	1.70	2.00	1.97	4.64	3.64	2.08	1.83	1.10	1.14	24.55
TEXAS																
Alpine	Brewster	8	4,482	.14	.36	.62	.49	1.00	1.86	2.24	2.16	2.24	1.50	.70	.79	14.10
Balmorhea	Reeves	7	3,225	.15	.49	.58	.88	.98	1.27	1.92	2.21	2.16	1.71	.50	.72	13.57
Barstow	Ward	13	2,573	.18	.26	.44	.64	.67	.79	1.59	1.27	1.86	1.67	.77	.50	10.64
Buena Vista	Pecos	18	2,416	.32	.47	.45	1.30	1.36	1.07	.73	1.63	2.27	1.36	.79	.45	12.20
Comstock	Val Verde			.52	.11	.36	4.82	2.85	3.42	1.49	1.56	2.46	.68	.92	.48	19.67
Del Rio	Val Verde	25	957	.40	.77	.90	1.65	2.31	2.04	2.34	1.35	2.28	2.57	1.33	.69	18.63
Ft. Davis	Jeff Davis	22	4,800	.47	.45	.35	.58	1.16	1.84	3.17	3.46	2.68	1.36	.60	.54	16.86
Ft. Stockton	Pecos	33	3,050	.38	.52	.56	.76	1.48	1.70	1.88	2.17	2.90	1.40	.71	.87	15.13
Grand Falls	Ward	18	2,300	.22	.50	.72	1.17	1.14	1.02	.99	1.55	2.17	1.35	.64	.54	12.01
Honey	Pecos	7	3,750	.20	.73	.48	.55	1.53	.98	1.52	2.71	2.18	2.14	.45	.67	14.12
Kent	Culberson	8	4,213	.43	.44	.28	.43	.66	1.58	2.14	2.17	1.93	1.28	.92	.47	12.73
Marathon	Brewster	7	4,043	.50	.78	.52	1.02	1.82	2.51	2.41	1.82	2.67	1.41	1.02	1.05	17.53
Marfa	Presidio	7	4,689	.15	.41	.47	.69	.53	2.38	2.07	1.64	1.63	.91	.65	.58	12.11
Midland	Midland	22	2,779	.46	.74	.64	1.48	2.17	1.95	1.51	2.00	2.02	1.58	.73	.63	15.91
Sanderson	Terrel	8	2,777	.40	.22	.24	.69	2.17	1.52	.63	.96	2.06	2.10	.52	.57	12.08
Sub-Station #14	Sutton	9	2,600	.61	1.13	1.58	2.18	3.10	2.39	1.47	1.76	2.73	3.93	1.37	1.69	23.94

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of precipitation during certain years. On the other extreme, 24 hour rainfalls of 7.71 and 8.88 inches have been recorded at Arabela, New Mexico, and Del Rio, Texas, respectively. In the mountain ranges much of the precipitation is in the form of snow. The Davis Mountains receive 8 to 10 inches of snow annually, the White Mountains receive 30 to 70 inches, and the Sangre de Cristo Range receives as much as 80 to 90 inches annually. From the New Mexico-Texas state line to the mouth of the Pecos, snowfall is negligible except for the mountain ranges.

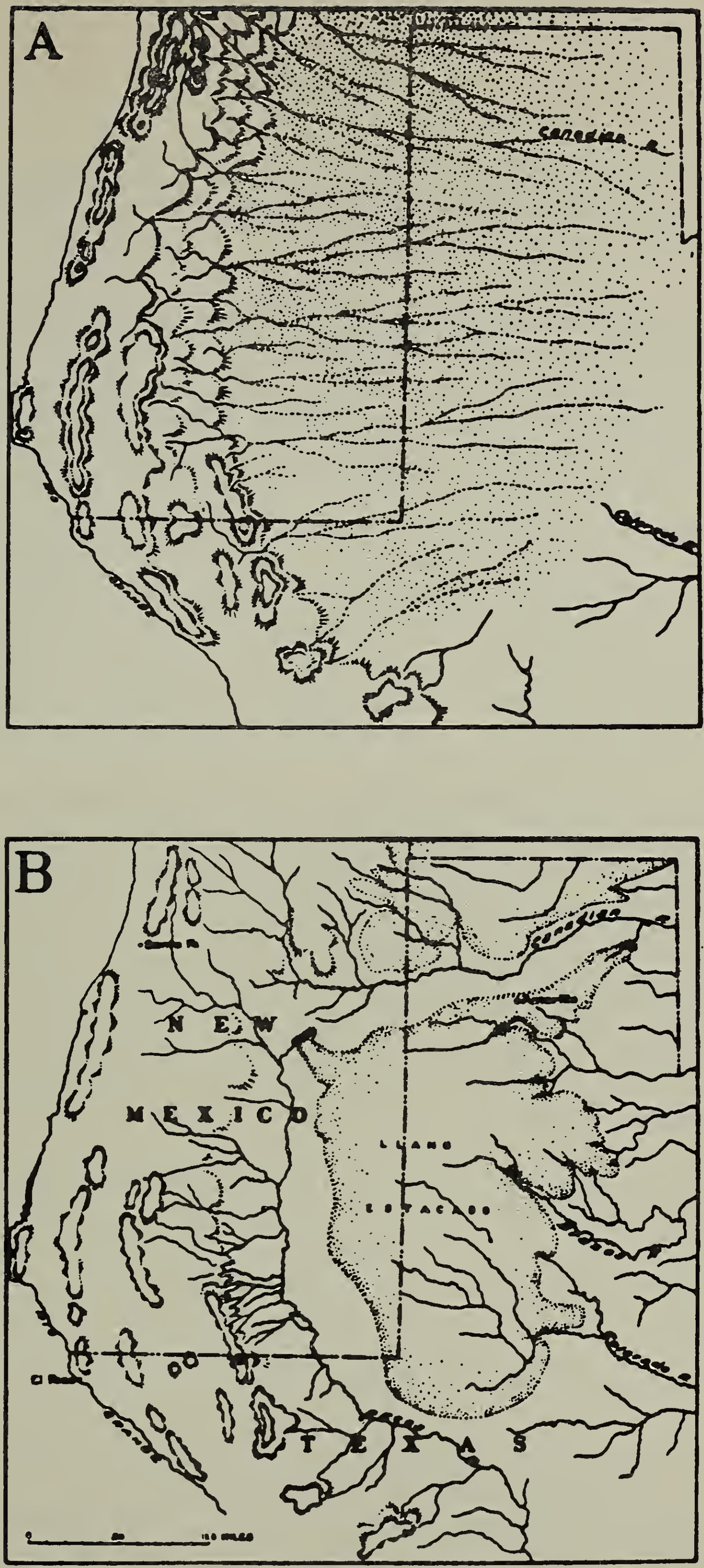
10. The mean annual temperature for stations within the watershed varies from 69.2 degrees at Del Rio to 41.1 degrees at Harvey's ranch above Pecos, New Mexico, in the upper watershed. Temperatures of 114 degrees have been recorded at Barstow and Fort Stockton, Texas. Winter temperatures as low as minus 31 degrees have been recorded at Las Vegas, New Mexico. The length of the growing season varies from 155 days at Las Vegas, New Mexico, to 277 days at Del Rio, Texas.

11. Annual evaporation rates vary from 50 inches near Santa Fe to 71.4 inches at Avalon Reservoir, Carlsbad. Winds from the south and southwest prevail during all but the winter months when they are from the west. The highest average wind velocities occur during the spring months and velocities of 50 miles per hour have been recorded.

Geology

12. Physiographic development.--Geologic structure and the characteristics of the formations have been controlling factors in the development of the topography of the Pecos River watershed. Diminishing precipitation, solution and removal of materials, subsidence, and headward erosion have been the principal agents in fashioning the present land surface. Available evidence indicates that development of this drainage system has taken place during Pleistocene and Recent geologic time. Figure 1 illustrates the interpreted early drainage pattern as compared with the present.

13. The alluvium of the Llano Estacado (Staked Plain) extended westward to the eastern foot of the Rocky Mountains at the close of the Pliocene epoch. This broad apron of sediments was laid down by large streams originating in the mountains under humid conditions. It is probable that as the depositional surface neared final development, an increasingly arid climate reduced the flow of the streams. They were unable to maintain through channels across the lowlands and as a result large amounts of water percolated underground. The increased subsurface



Evolution of the physiography of northwest Texas and southeastern New Mexico. A, Area during Pliocene times showing alluvial deposits east of the high mountains in New Mexico. B, Area during present epoch showing capture of eastward-flowing streams of Pliocene times by the head-waters of Pecos River.

Figure 1

REFERENCE: Bulletin 3232, page 770, The Geology of Texas, Vol. I, Stratigraphy Bureau of Economic Geology, University of Texas, 1932.

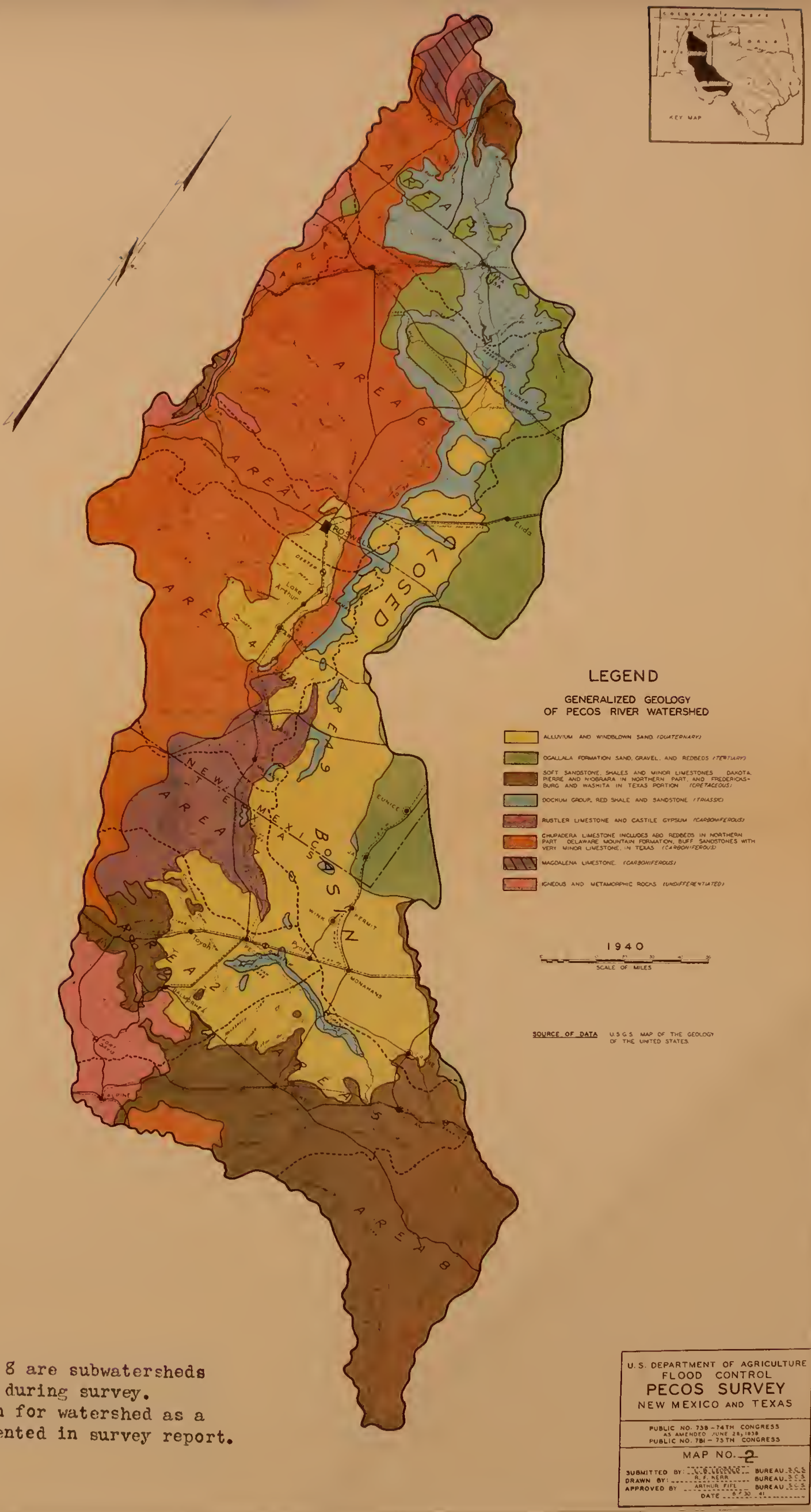
flow dissolved and removed thick soluble beds of early Triassic and Permian age, which lay at relatively shallow depths beneath the alluvial mantle.

14. In time "sinks" developed due to the collapse of the solution cavities. The location and position of the soluble formations (salt, anhydrite, and limestone) set the pattern for a series of depressions which gradually developed across the existing surface slope. The chain of "subsidence areas" extended in a general north-south direction along the strike of the soluble beds. The individual "sinks" became connected through continued solution and by erosion due to overflow during floods. In this way an elongated depression or trough was formed approximately at right angles to the former stream channels. Meanwhile a tributary of the ancestral Rio Grande, advancing north by headward erosion, reached the southern area of sinks. Eventually, this stream worked northward through the chain of sinks and intercepted the eastward flowing streams to form the present Pecos River system.

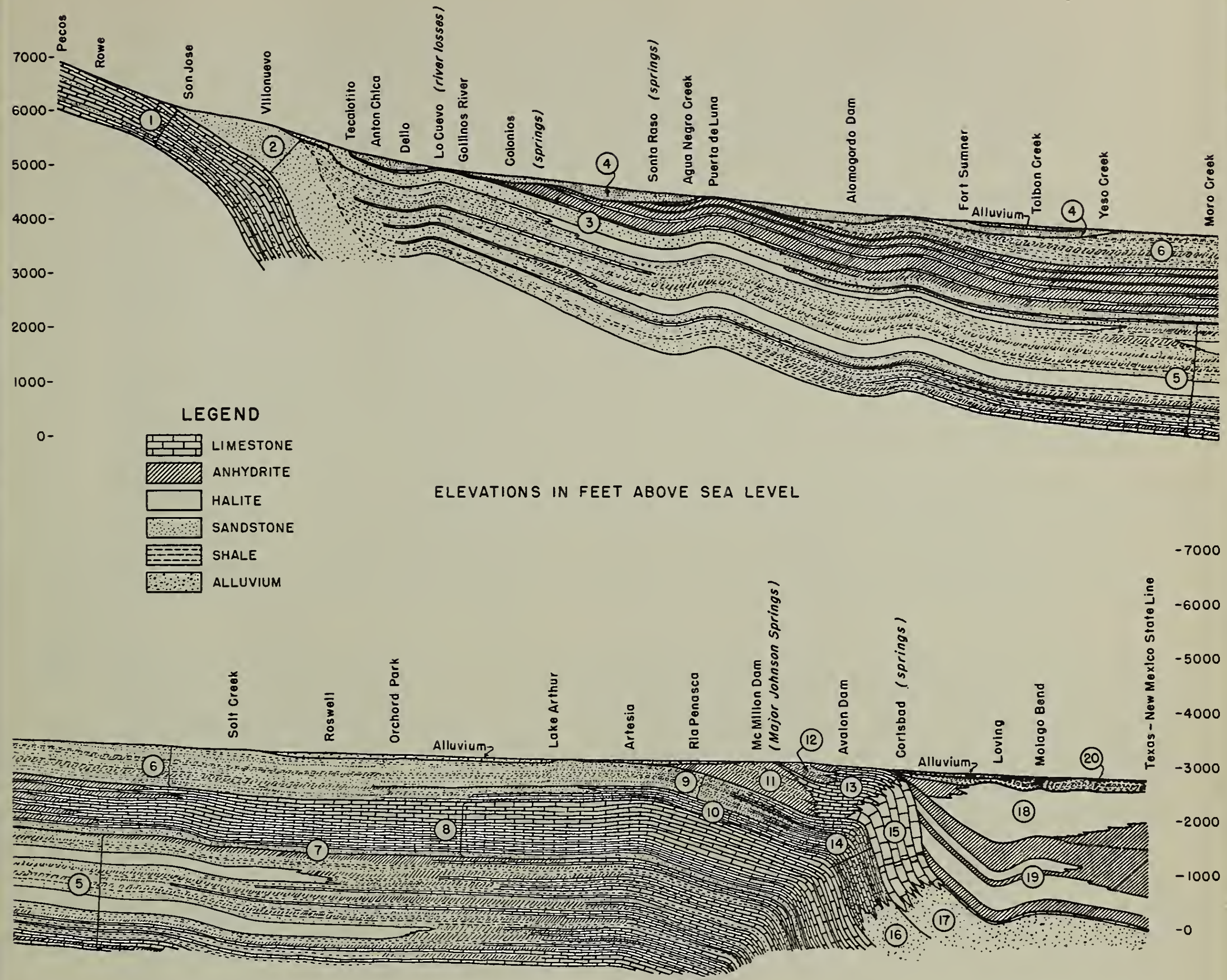
15. Stratigraphy.--Sedimentary rocks, ranging from early Carboniferous to Recent geologic time, outcrop over the major portion of the watershed. Igneous and metamorphic rocks, undifferentiated as to class or age, occupy a limited area in the uplands on the west. Map 2 shows the areal distribution of the several formations, a brief description of which follows. The oldest of the strata, the Magdalena limestone (Pennsylvanian) outcrops in a small area on the headwaters of the Pecos River. Here the formation consists of a series of dark to gray, dense, fossiliferous limestones. The layers are jointed, thin to thick bedded, and interlain with gray and red shale and sandstone members.

16. The Chupadera Group.--(Permian) is exposed over much of the western half of the watershed. This group, shown on the geologic map as including the Abo sandstone and the Delaware Mountain formation, covers an area greater than any of the other formations. Because of their extensive exposure and peculiar physical characteristics, the Chupadera strata have been an important factor in the physiographic and cultural development of the Pecos section. Some members of the formation are subject to rapid lateral gradation of facies such as the change from anhydrite to limestone of the San Andres in the valley north of Roswell. Figure 2 illustrates the gradations which occur longitudinally in the New Mexico portion of the area. The Chalk Bluff, or Whitehorse group, thickens south of Artesia, grading into the Delaware Mountain group as indicated on Figure 2.

17. The upper Permian beds comprise the Castile, Salado, and Rustler formations. These beds outcrop in the area south and east of Lake



Areas 1 to 8 are subwatersheds considered during survey. Information for watershed as a whole presented in survey report.



(1) Magdalena fm.
(2) Abo ss.
(3) Glorieta ss.
(4) Santa Rosa ss.
(5) Yeso fm.
(6) Chalk Bluff fm.
(7) Hondo ss.
(8) San Andres fm.
(9) Queen ss.
(10) Grayburg fm.
(11) Seven Rivers fm.
(12) Yates ss.
(13) Carlsbad ls.
(14) Dog Canyon ls.
(15) Capitan ls.
(16) Cherry Canyon fm.
(17) Bell Canyon fm.
(18) Salado fm.
(19) Castile fm.
(20) Rustler fm.

Figure 2

GEOLOGIC CROSS SECTION ALONG THE PECOS RIVER PECOS, NEW MEXICO TO THE STATE LINE

10 5 0 10 20 30 40 50
Scale in Miles

REFERENCE: Prepared by A.M. Morgan, U.S.G.S., Department of the Interior. Plate I. Geologic Cross Section along the Pecos River from Pecos, New Mexico to the State Line. The Pecos River Joint Investigation Reports of Participating Agencies—1942. National Resources Planning Board.

McMillan. They extend southward in a broad band along the river and on the west side of the valley to the latitude of Pecos, Texas. The upper Permian strata lie between the Whitehorse or Chalk Bluff formation and the overlying Dockum group (Triassic). The latter formation outcrops over a considerable area in the northern part of the watershed in the vicinity of Santa Rosa. A narrow belt extends southward on the east side of the river as far as Artesia. Limited exposures are present in southeastern New Mexico and western Texas. The Dockum beds in New Mexico consist of the basal Santa Rosa sandstone and a thick series of red shale. The Santa Rosa in its type area is made up of two buff-to-gray sandstone beds separated by a shale and sandstone member. The total thickness is approximately 350 feet. The overlying red shales with a maximum thickness of about 1,000 feet, are interbedded with thin sandstones. East of the river in southern New Mexico and west Texas, the Pierce Canyon series lies beneath the Santa Rosa sandstone. This series, here approximately 350 feet thick is composed of fine red sandstones, shaly sandstones, and sandy shales. The lower part of the Pierce Canyon redbeds is considered by some geologists as being of Permian age. The name "Dewey Lake" has been proposed for these beds.

18. Rocks of the Jurassic and Cretaceous periods are exposed on and lie beneath a small area in the northern part of the basin near Las Vegas. Cretaceous rocks outcrop over a large portion of the Pecos watershed in Texas. They are exposed on the mountain slopes west and southwest of Pecos, Texas. Limestones of this period cap and underlie the Edwards Plateau, which comprises about one-sixth of the entire Pecos drainage area.

19. The Ogallala formation (Tertiary) covers extensive areas in the eastern and north-central sections of the watershed. The deposit ranges from 200 to 650 feet in thickness. It consists of gravels overlain by sand, sandy clay, windblown material, and small quantities of volcanic ash. A thin layer of limestone sometimes occurs near the top of the formation. The sands, clays, and silts are unconsolidated except for occasional lenses and beds cemented by caliche. Stratification, when present, is lenticular and typical of continental deposits. Existing exposures are remnants of a once continuous alluvial plain which extended eastward from the mountains at the close of the Pliocene epoch.

20. The Quaternary deposits in the Pecos Valley consist of stream terraces, recent alluvium, sand, and loess. The materials are generally unstratified and unconsolidated. They cover considerable areas in the central, eastern, and south central portions of the watershed.

21. <u>Structure</u>.--The Pecos River watershed is located on the eastern limb of a broad arch formed by uplift of the Rocky Mountains. The sedimentary formations, which outcrop within and underlie the area, dip to the east

and southeast, generally at low angles. The older strata thus outcrop in areas progressively further westward while the more recent beds occupy the eastern portion of the basin except where cut deeply by tributary canyons. Faults have been a factor in the development of the mountain ranges bordering the area on the west. They are not, however, an important feature of geologic structure within the watershed except in a few localities. South and west of Balmorrhea and Fort Stockton, Texas, faulting is believed responsible for the occurrence of several large springs which issue from Cretaceous limestones in a general east-west line.

22. The river turns southeastward near Becos, Texas, and leaves the alluvium-filled Delaware Basin. Thence it flows generally eastward for many miles on Triassic beds exposed across the Pecos Uplift (Central Basin Platform) as noted in fig. 3. East of the Central Basin platform, south of Crane, Texas, the Pecos enters the Lower Cretaceous series of the Edwards Plateau. These strata, chiefly limestones, lie in a broad, gently southward plunging syncline which the river traverses to its confluence with the Rio Grande.

Soils

23. General.--Soils of the Pecos River watershed range widely in depth, texture and development by reason of climatic, physiographic, and parent material variations. Soils are grouped on a basis of depth to bedrock or other type of unproductive layer (maps 3,4,5,6,7). Shallow soils have an effective depth of 10 inches or less, medium depth soils range from 10 to 30 inches deep, and deep soils exceed 30 inches in effective depth. This type of classification is useful in locating critical sediment source areas. Also, soil depth is an important factor in evaluating the potential productive capacity of watershed areas upon which certain types of remedial measures are proposed in the interest of flood control. General soil groups and corresponding percentages of the watershed they occupy are: 1) deep alluvial (valley lands), 4 percent; 2) deep upland, 15 percent; 3) medium depth upland, 24 percent; 4) shallow upland, 43 percent; 5) deep loose sand, 2 percent; and 6) shallow gravelly and stony (mountain areas), 12 percent. A general description of these soil groups follows.

24. Deep alluvial soils.--Large terraces, overlapping fans, and bottoms of varying width along the Pecos River and its tributaries make up the group. They consist of thick layers of alluvial material derived from upland slopes. Profiles are slightly altered by weathering, range widely in texture and gravel content, but are generally productive when irrigated. Topsoils are resistant to sheet erosion, but channel

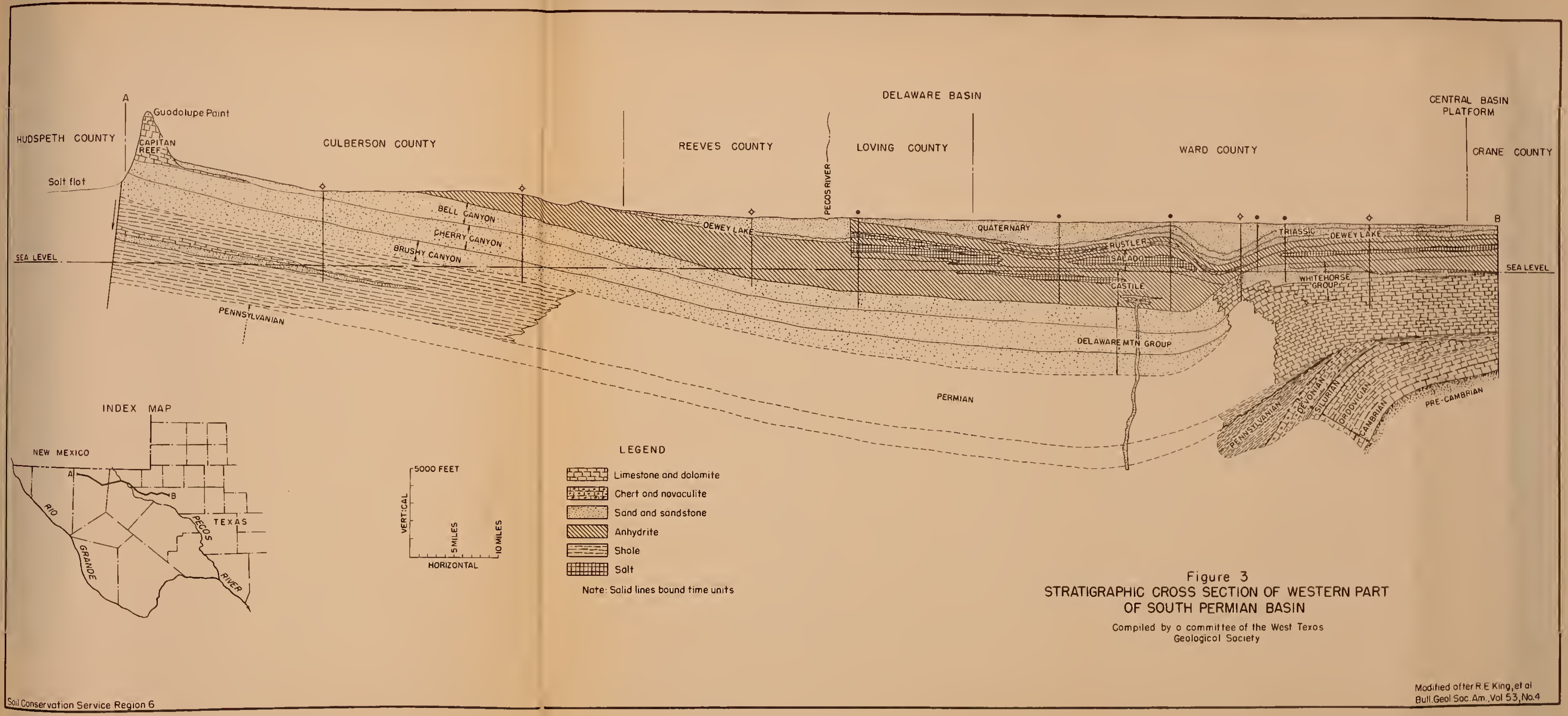
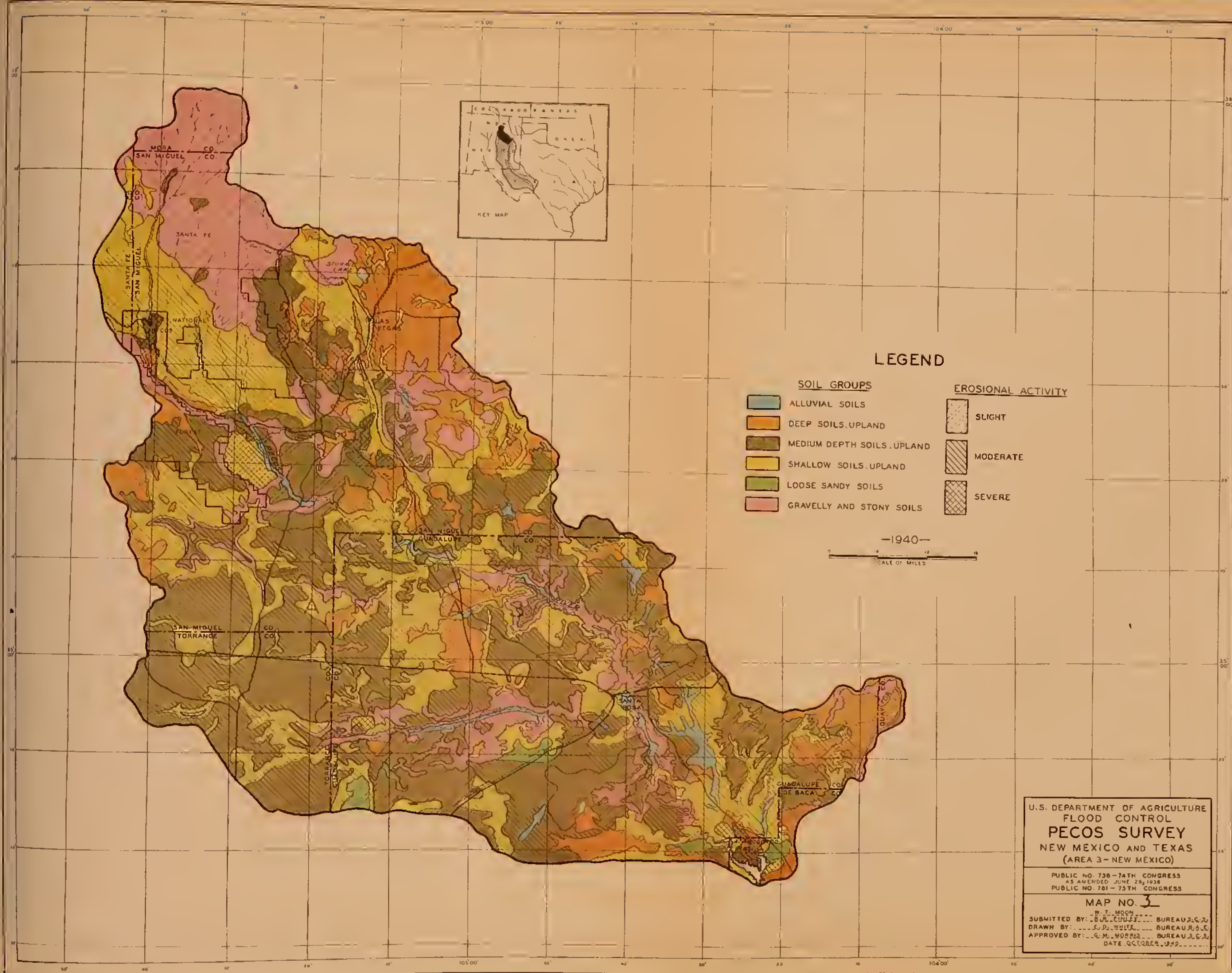
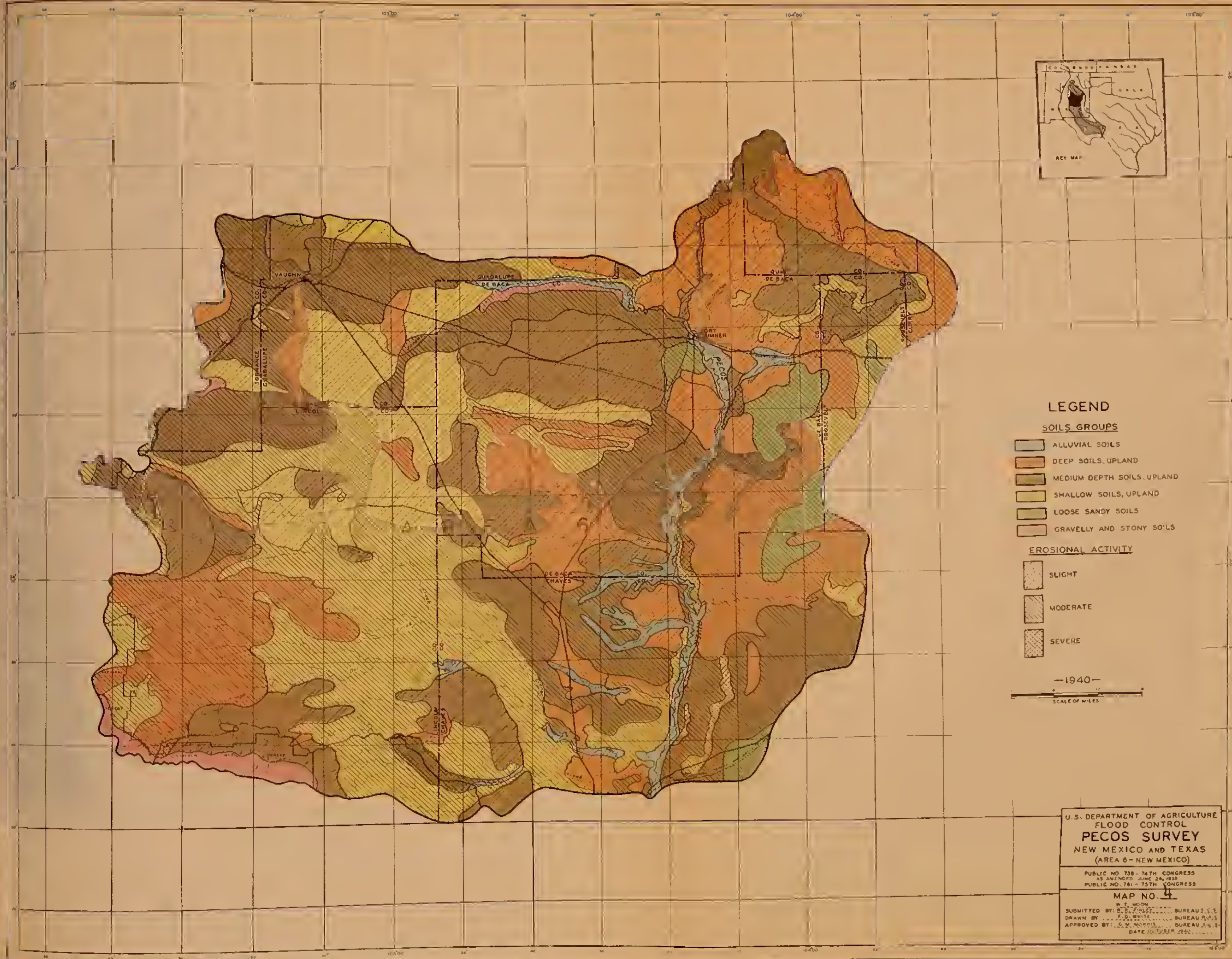


Figure 3
STRATIGRAPHIC CROSS SECTION OF WESTERN PART OF SOUTH PERMIAN BASIN

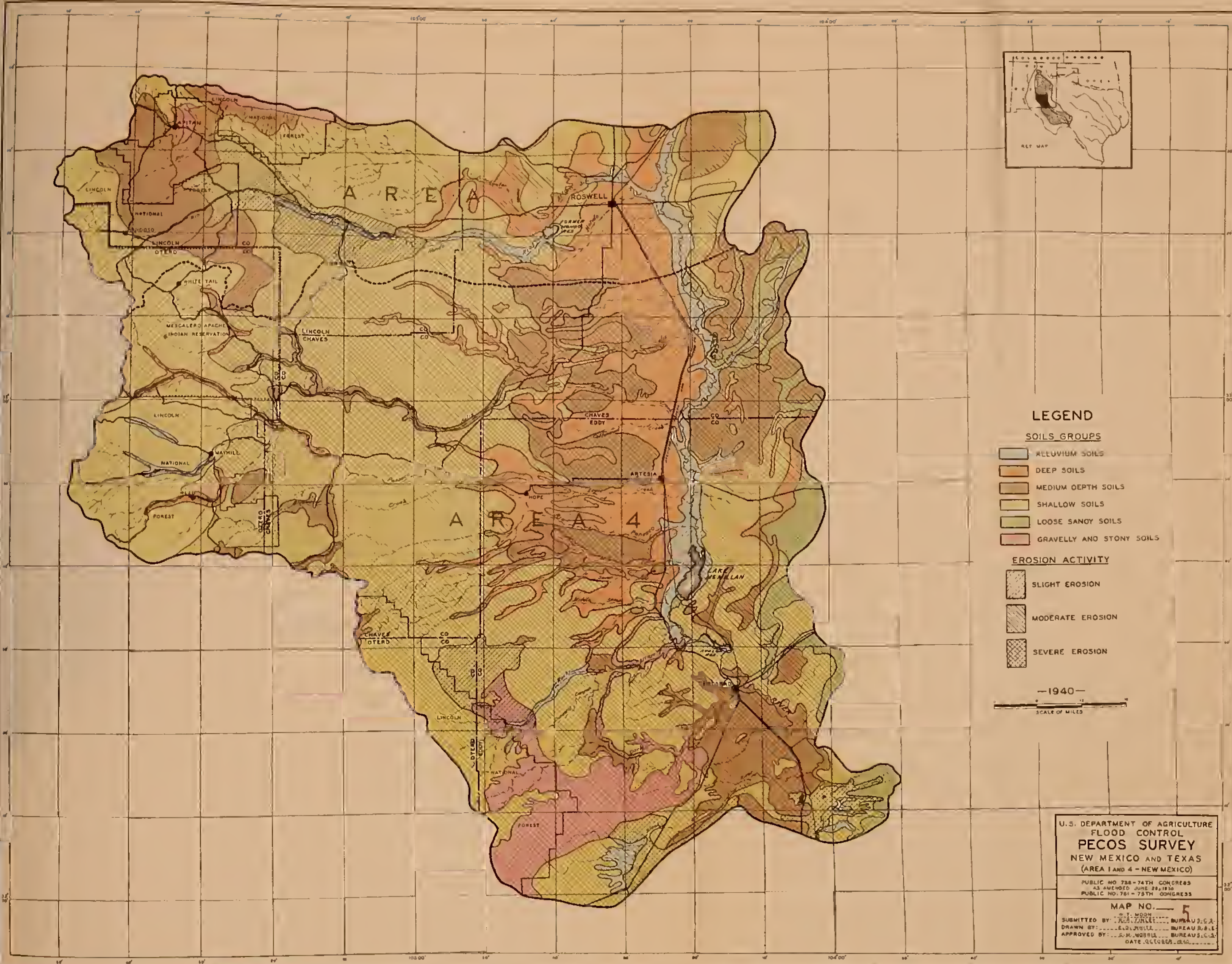
Compiled by a committee of the West Texas Geological Society



LEGEND
SOIL GROUPS
ALLUVIAL SOILS
DEEP SOILS, UPLAND
MEDIUM DEPTH SOILS, UPLAND
SHALLOW SOILS, UPLAND
LOOSE SANDY SOILS
GRAVELLY AND STONY SOILS
EROSIONAL ACTIVITY
SLIGHT
MODERATE
SEVERE
—1940—
KEY MAP
MORA CO.
SAN MIGUEL CO.
SANTA FE
SAN MIGUEL
GUADALUPE
SAN MIGUEL
TORRANCE
GUADALUPE
DE BACA
U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL
PECOS SURVEY
NEW MEXICO AND TEXAS
(AREA 3 - NEW MEXICO)
PUBLIC NO. 738 - 74TH CONGRESS
PUBLIC NO. 761 - 75TH CONGRESS
MAP NO. 3
W. T. MOON
SUBMITTED BY: BUREAU
DRAWN BY: BUREAU
APPROVED BY: BUREAU
DATE



LEGEND
SOILS GROUPS
ALLUVIAL SOILS
DEEP SOILS, UPLAND
MEDIUM DEPTH SOILS, UPLAND
SHALLOW SOILS, UPLAND
LOOSE SANDY SOILS
GRAVELLY AND STONY SOILS
EROSIONAL ACTIVITY
SLIGHT
MODERATE
SEVERE
—1940—
SCALE OF MILES
KEY MAP
VAUGHN
GUADALUPE
DE BACA
FORT SUMNER
PECOS
DE BACA
CHAVES
LINCOLN
CHAVES
TORRANCE
GUADALUPE
ROOSEVELT
CURRY
U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL
PECOS SURVEY
NEW MEXICO AND TEXAS
(AREA 6 - NEW MEXICO)
MAP NO. 4
SUBMITTED BY:
DRAWN BY
APPROVED BY:
DATE



AREA 1
AREA 4
ROSWELL
ARTESIA
HOPE
CAPITAN
RUIDOSO
WHITE TAIL
MAYHILL
LAKE MCMILLAN
MESCALERO APACHE INDIAN RESERVATION
LINCOLN NATIONAL FOREST
LINCOLN
OTERO
CHAVES
EDDY
CO
LEGEND
SOILS GROUPS
ALLUVIUM SOILS
DEEP SOILS
MEDIUM DEPTH SOILS
SHALLOW SOILS
LOOSE SANDY SOILS
GRAVELLY AND STONY SOILS
EROSION ACTIVITY
SLIGHT EROSION
MODERATE EROSION
SEVERE EROSION
—1940—
SCALE OF MILES
KEY MAP
U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL
PECOS SURVEY
NEW MEXICO AND TEXAS
(AREA 1 AND 4 – NEW MEXICO)
MAP NO. 5
SUBMITTED BY
DRAWN BY
APPROVED BY
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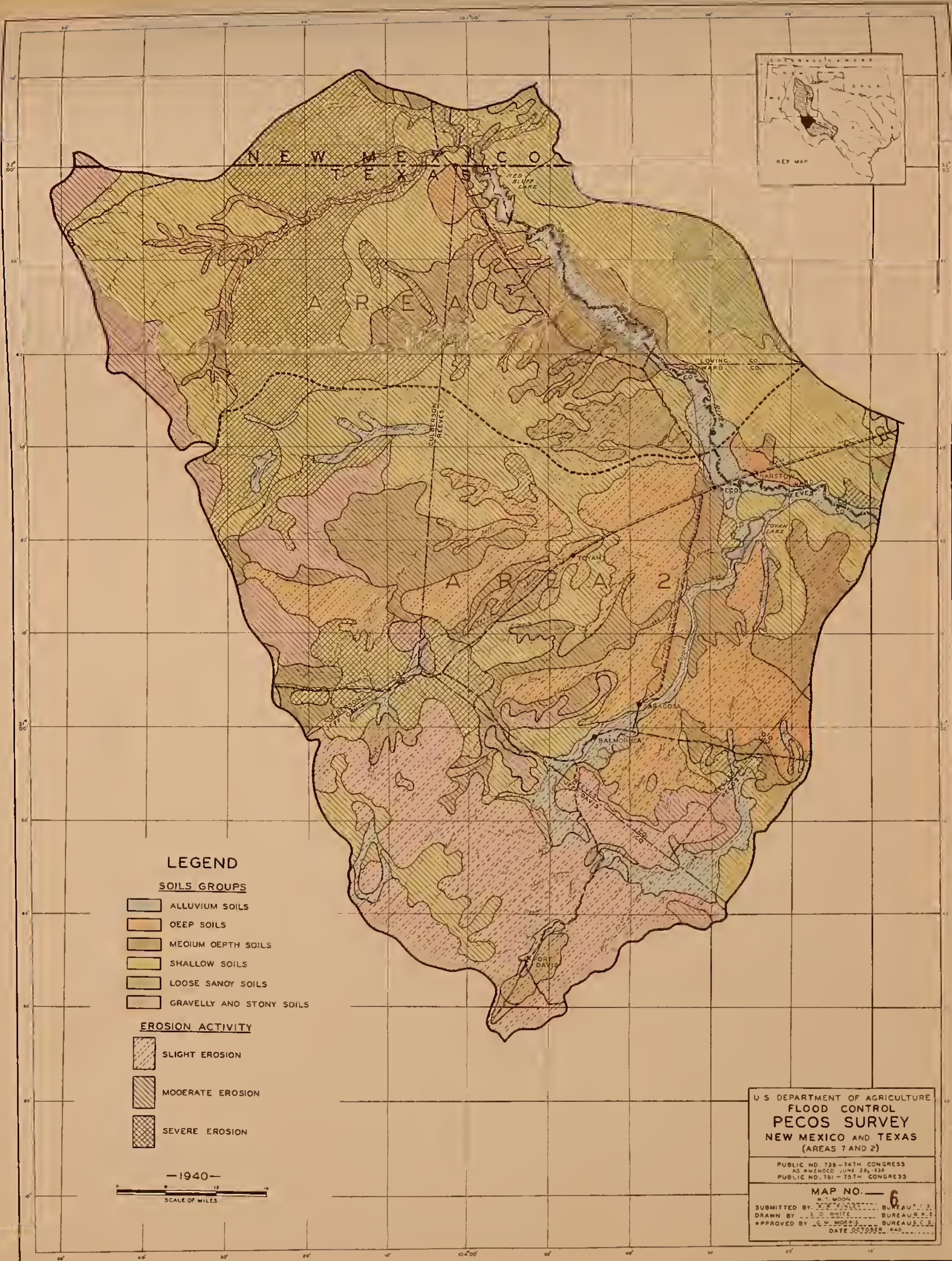
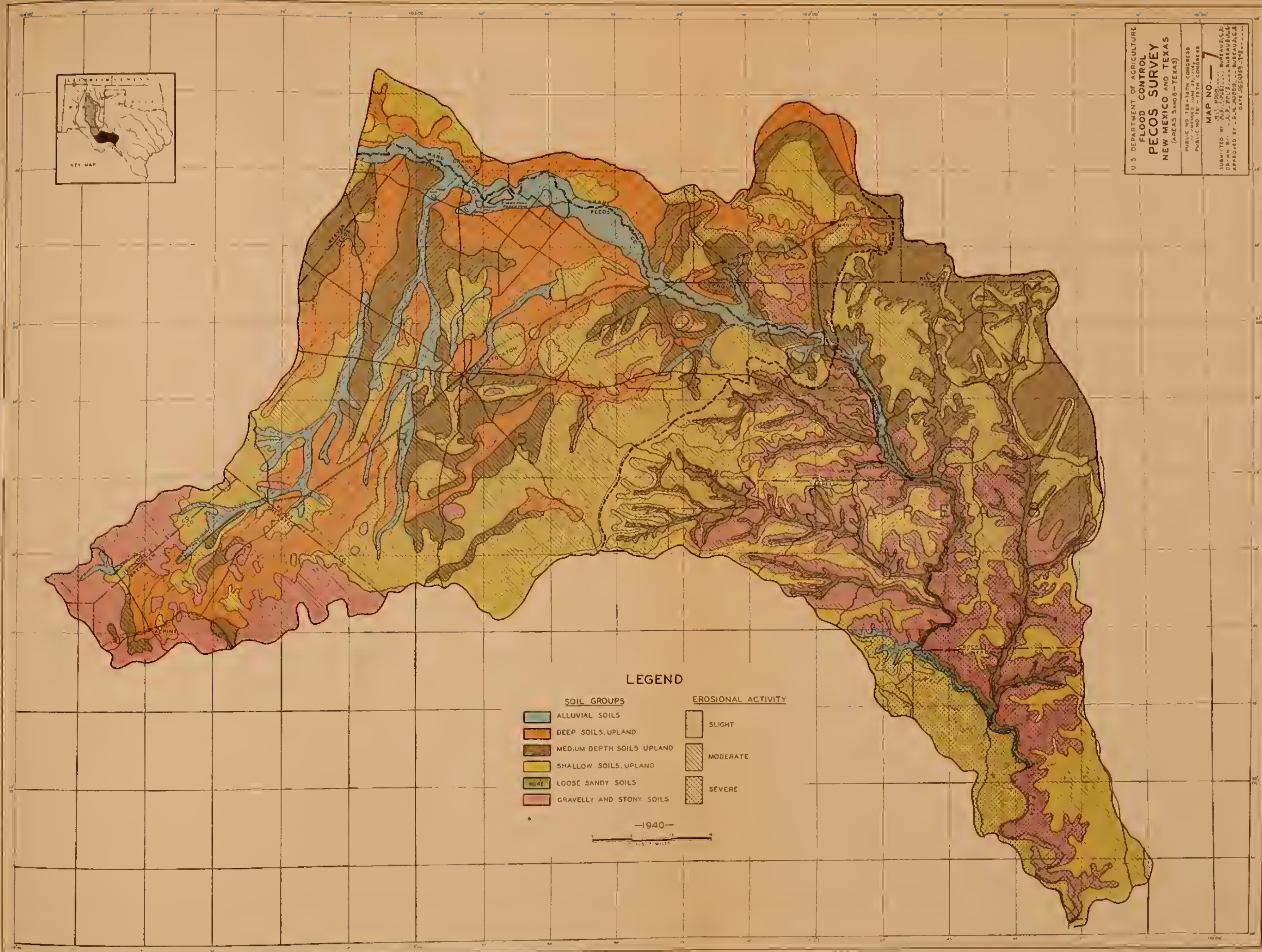

NEW MEXICO
TEXAS
RED BLUFF LAKE
AREA 7
AREA 2
CULBERSON
REEVES
LOVING CO.
WARD CO.
PECOS
BARSTOW
REEVES CO.
TOYAH
TOYAH LAKE
SARAGOSA
BALMORHEA
JEFF DAVIS
FORT DAVIS
KEY MAP
LEGEND
SOILS GROUPS
ALLUVIUM SOILS
DEEP SOILS
MEDIUM DEPTH SOILS
SHALLOW SOILS
LOOSE SANDY SOILS
GRAVELLY AND STONY SOILS
EROSION ACTIVITY
SLIGHT EROSION
MODERATE EROSION
SEVERE EROSION
—1940—
SCALE OF MILES
U S DEPARTMENT OF AGRICULTURE
FLOOD CONTROL
PECOS SURVEY
NEW MEXICO AND TEXAS
(AREAS 7 AND 2)
PUBLIC NO. 738 – 74TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 – 75TH CONGRESS
MAP NO. 6
SUBMITTED BY
DRAWN BY E. D. WHITE
APPROVED BY G. M. MORRIS
DATE OCTOBER 1940


U S DEPARTMENT OF AGRICULTURE
FLOOD CONTROL
PECOS SURVEY
NEW MEXICO AND TEXAS
(AREAS 5 AND 6 — TEXAS)
MAP NO. 7
KEY MAP
PECOS
LEGEND
SOIL GROUPS
ALLUVIAL SOILS
DEEP SOILS, UPLAND
MEDIUM DEPTH SOILS UPLAND
SHALLOW SOILS, UPLAND
LOOSE SANDY SOILS
GRAVELLY AND STONY SOILS
EROSIONAL ACTIVITY
SLIGHT
MODERATE
SEVERE
—1940—

trenching and bank caving, indicating a deteriorated watershed condition, are proceeding in numerous locations. In these areas originate a substantial part of the sediment depositing in reservoirs and on farm land. Coarse debris flushed from side arroyos frequently damages mountain valley farms. An arid climate limits land use to irrigated farming or grazing.

25. Deep upland soils.--Deep soils are widespread and occur on gently sloping lands. The largest bodies occupy positions midway between shallow uplands and river bottoms. Their parent materials are most generally identified with the old alluvial apron laid down during the Rocky Mountain uplift period, but limestone areas make up a substantial part. Profiles are medium to heavy textured, and compared with other groups, are well developed. A caliche hardpan, generally occurring below 30 inches, restricts deep percolation of water in a large part of the area. Topsoils are moderately resistant to sheet erosion, but in recent years gullies originating near the main stream channels are trenching back into the uplands. The area affected by gullies is small, yet the amount of sediment produced is large. An arid climate limits land use to grazing except where irrigation water is available. Several small tracts are being dry-farmed, but yields are low and erosion activity is high.

26. Medium depth upland soils.--Medium depth soils are widespread, occurring on rolling to gently undulating topography throughout the watershed. Their profiles range from ten to thirty inches in depth, are medium to moderately heavy textured, and are slightly less fertile than the deep soil group. The principal areas are underlain by limestone or hard caliche, but shale, sandstone, and igneous rock constitute a substantial part. Mountain types exhibit well-developed, permeable profiles that are highly resistant to erosion. Soils at lower elevations, deepened by accumulations from adjacent slopes, are poorly developed but frequently include areas with caliche hardpan that inhibits deep percolation of water. Their infiltration capacities are low by reason of poor vegetative cover and surface layers that have been disturbed by erosion. Because of moderately thick erodible profiles coupled with a deteriorated watershed condition, gully and sheet erosion are common and sediment production is high except in the mountain zones. The group is utilized entirely for grazing purposes.

27. Shallow upland soils.--Shallow soils are extensive, occurring in the mountains, on the rolling plains, and on the Edwards Plateau. Their profiles average less than 10 inches thick, are slightly weathered, and range in texture from medium to moderately heavy. The principal areas are underlain by limestone, igneous or gypsum rock, but some shale and sandstone areas occur. Mountain soils with above-average organic matter and surface litter, along with good vegetative cover, have favorable

infiltration capacities and are resistant to erosion. At lower elevations of rolling or dissected topography with poor cover, run-off is high but sediment production is low by reason of thin soil mantle, stony or gravelly surface layers, and hardrock substrata. Narrow alluvial valleys situated in extensive areas of shallow soils contribute much of the sediment coming from the areas. An arid climate, together with thin, stony unstable profiles, limit land use to grazing.

28. Deep loose sandy soils.--Loose sandy soils are of limited extent in the watershed. They occur with few exceptions east of the Pecos River, extending south from Fort Sumner, New Mexico, and ending near Monahans, Texas. They are light textured and low in organic matter. Depth generally exceeds thirty inches but varies widely. Underlying materials are sandstone, limestone, caliche, and shale. Except for the sandstone areas, the sand is of foreign origin and is not related to the underlying rock. Productivity is moderate to low since the climate is arid and soil fertility is low. Susceptibility to wind erosion is high and they deteriorate rapidly as soon as cover is depleted. Because drainage systems are poorly developed or absent, run-off and sediment production are low and unimportant. Surface relief is gently undulating or hummocky.

29. Shallow gravelly and stony soils.--Gravelly and stony soils occur in the mountains and the steep breaks bordering the major streams. Normal erosion is keeping pace with soil formation, and consequently the mantle of soil is very thin or missing. Bare rock and ancient gravel beds interspersed with small pockets, shelves, and swales of accumulated soil make up the group. Surface relief is steep and mountainous. Climatic environment varies from subhumid in the high mountains to arid in the lower elevations.

30. Surface erosion both geologic and accelerated is active but sediment yield is low, due to shallow profiles and hard rock substrata that prevent gullying. This soil group, excluding the forested portion, is a critical flood source area. Slopes are steep and dissected and vegetative cover is thin or entirely absent.

Plant Cover

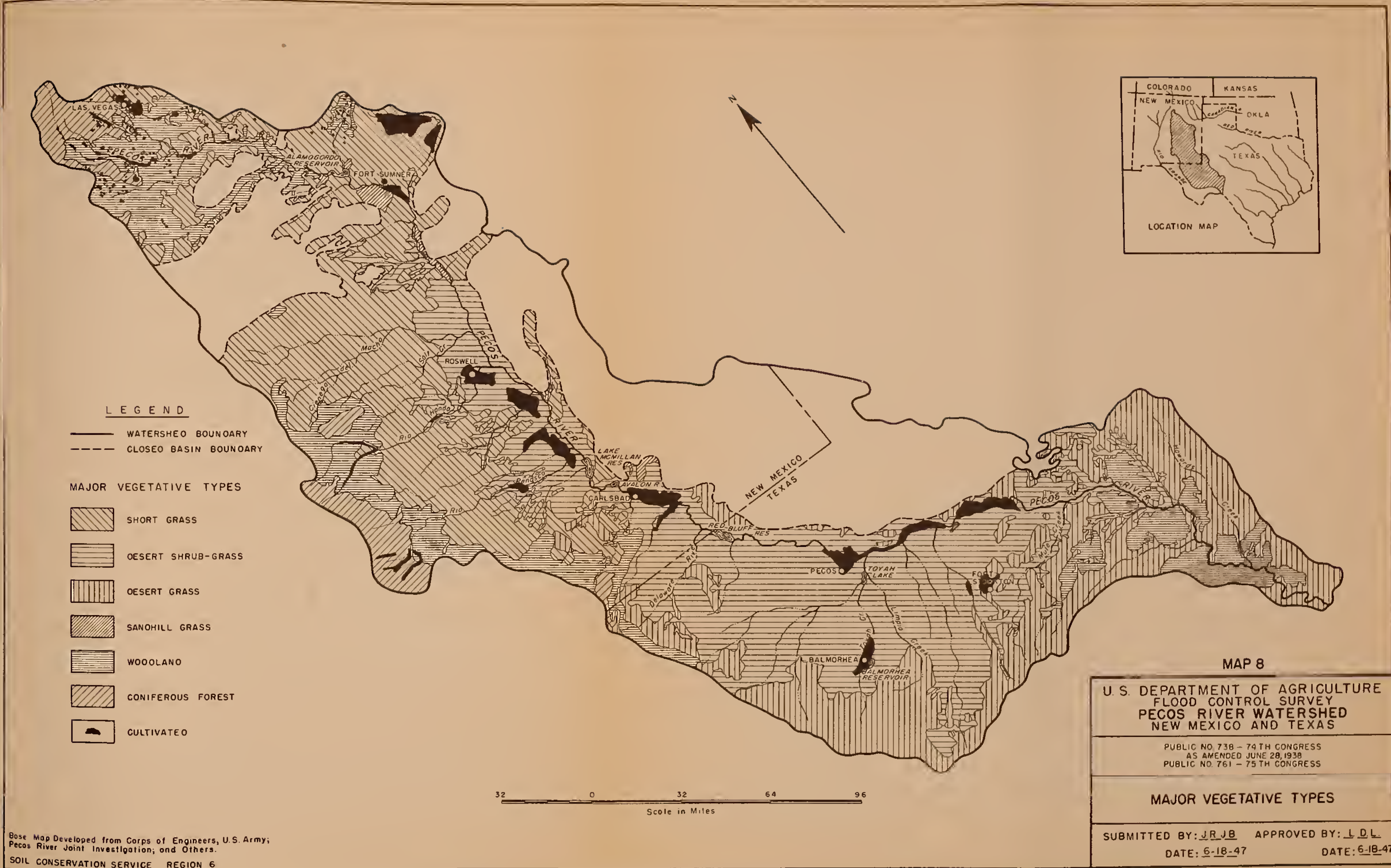
31. General.--As in most of the Southwest, a wide variety of vegetation occurs in response to marked differences in topography and climate (map 8). Broad vegetative types and percentage of the watershed they occupy are: 1) short grass, 31 percent; 2) desert shrub-grassland, 31 percent; 3) desert grass, 18 percent; 4) sandhill grass, 1 percent, 5) woodland, 14 percent; and 6) coniferous forest, 5 percent.

32. The vegetation of the Pecos watershed was effective at one time in checking soil movement as is indicated by the development of the soils. The canopy of a coniferous forest shielded soil against damaging effects of rainfall and a heavy litter over the ground surface, which acted as an absorptive mat, further protected soils from the destructive forces. Here soils are highly developed. In contrast, desert shrub-grasslands had less protective cover and soils are not so well developed. Both these extremes and the intermediate stages of soil development found on woodlands and grasslands are the product of normal processes. Where ground cover is not deteriorated, there is a balance between soil and vegetation. Throughout the basin except in the mountainous portions, long grassy swales which sloped toward the Pecos were situated between ridges on which less dense vegetation occurred. Run-off from the hillsides maintained the productivity of the swales which in turn retarded flash floods.

33. Livestock use without regard to forage produced, particularly during extended periods of drought, has resulted in decreased density and vigor of the grass. The process is one of continual decline. With loss of vigor and density, root systems become smaller and litter accumulation lighter. This results in less resistance to surface run-off by lowering the infiltration rate and water-holding capacity of the soil. Surface run-off and soil erosion increase as plant cover decreases.

34. Short grass.--Short grass predominates on the high plains in the northern portion of the watershed. The principal grass species on a good range are: blue grama, side-oats grama, hairy grama, black grama, galleta, dropseed, and bluestem. With improper use, undesirable species such as three-awn, ring muhly, burro grass, fluff grass, and snakeweed become dominant.

35. Desert shrub-grassland.--Originally the true desert shrub climax occurred where rainfall is less than 8 inches and on rocky knolls and talus slopes. It now occupies the largest land area. It is found



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in the lower valley bottoms and adjoining desert plains where rainfall is much above 8 inches and where grasses formerly dominated the plant association.

36. Because of variation in soil and moisture relationships, this type is now divided into three associations: creosotebush-grassland, tobosa and sacaton grassland, and salt desert shrub-grassland. The creosotebush association occurs on the driest shallow soil locations and gives the least watershed protection. In good condition, the association contains black grama, bush muhly, sand dropseed, and three-awn grasses. In its present condition, shrubs are dominant with frequent occurrences of fluffgrass, which has no forage value. The tobosa-sacaton association occupies drainageways and flood plains. This is the highest producing association in the type. When conservatively used, sacaton, alkali sacaton, side-oats grama, plains beardgrass, bush muhly, vine mesquite, and tobosa make a good protective cover. The present deteriorated condition is indicated by the dominance of the shrubs, tarbush and mesquite. Burro and tobosa grass have crowded out the more desirable grasses. Salt desert shrub-grassland association occupies several large areas of gypsum and alkali soils. In good condition, the association contains alkali sacaton, saltgrass, and chino grama grass. The shrubs, chamiza, graythorn, and creosotebush, are scattered throughout the type. Shrubs and chino grama now dominate the type, and there are many large bare areas where erosion is severe. Forage of desert shrub-grassland varies from year to year, depending on annual grass and weed growth.

37. Desert grassland.--Desert grassland occurs south of the short grass plains. It occupies the low plateau country, which is broken by many large drainages. The good range grasses are: the grammas, black, blue, hairy and side-oats, together with curly-mesquite, bush muhly, bluestem, tanglehead, and spangletop. Due to improper use, tobosa, curly-mesquite, and burro grass, which are less desirable, have invaded the range, and thorny shrubs have become widespread.

38. Sandhill-grassland.--Sandhill-grassland occurs intermittently along the eastern portion of the watershed on loose sand or sandy loams. The principal grasses are big and little bluestem, side-oats grama, blue grama, sand dropseed, and Indian rice. The principal shrubs are mesquite, sand sage, shinoak, chamiza, and yucca. Sandhill-grassland is of relatively little importance from a watershed standpoint as it contributes little run-off or sediment. However, it is important in the management of adjacent flood and sediment contributing areas because of its value as winter and spring range. In its present deteriorated condition, shrubs are predominant. Grasses are reduced

to a thin stand and in some areas are absent. The sandhill-grassland is subject to blowing, and dunes are common where the grass has been removed. The dune area is a permanent loss for forage production.

39. Pinon-juniper woodland.--The woodland type occupies the foothills and mesas of the watershed. Principal tree species are pinon pine, one-seed juniper, alligator juniper, Rocky Mountain red cedar, and occasionally live oak. In the upper elevation, the trees form a fairly continuous cover, but throughout most of the type, they are sparse, growing in clumps or single stands. The grasses under proper land use are gramas, needlegrass, wheatgrass, beardgrass, bluegrass, fescues, and muhlys. Under poor land use, young junipers are common in openings which formerly were well-grassed areas. Grasses consist largely of low vigor blue grama and ring muhly. Thin stands of annual and perennial weeds are scattered throughout.

40. Coniferous forests.--Forests are limited to the mountains and high mesas of the New Mexico portion of the watershed. The type is used for grazing by both game and livestock. Two associations comprise the type, spruce-fir and pine. The spruce-fir occurs at elevations above 9,000 feet. This is the high water-yielding area of the watershed. It is valuable for timber production and as a dependable source of water for irrigation. Big game, elk and deer, is an important resource. The pine association occurs below 9,000 feet elevation and furnishes considerable grazing because of sparseness of stand.

Erosion

41. General.--The erosion classification locates critical sediment-source areas and indicates the physical condition of the watershed in terms of extent of loss of infiltration capacity and productivity. It is also useful in planning and evaluating a remedial program in the interest of flood control.

42. Erosion classes.--Type, degree, and extent of erosion were determined when the soil and vegetative surveys were made (maps 3,4,5,6,7). Three classes of erosion are: 1) slight water or wind removal denoting a loss of 25 percent or less of original topsoil; 2) moderate, showing a loss of 25 to 75 percent of surface soil; and 3) severe, indicating removal in excess of 75 percent of surface soil. Each class is further described as to frequency and depth of gullies. Gullies, where they occur, are designated as deep (over 3 feet deep), shallow (less than 3 feet deep), frequent (3 or more gullies per acre), and occasional (less than 3 gullies per acre). Percentages of the watershed affected by the various classes of erosion are: slight, 34; moderate, 59; and severe, 7.

43. History.--The watershed was originally protected by vegetative cover that regulated run-off and prevented soil movement. This protective cover became depleted as the livestock operations of settlers expanded. Soil erosion was accelerated as the vegetation deteriorated. Damage caused by floods increased as agricultural areas were extended and as towns and cities developed within the flood plain. Much of the watershed suffered for many years from considerable topsoil removal and local gully activity, but it was not until trenching in the larger drainageways and bank caving on major streams became serious, that erosion reached a critical stage. Examination of records indicate a large part of the bank caving and trenching has occurred in the last 50 years. At present erosion is active over the entire watershed, sediment production rates are at an all-time high, and floods of damaging size are common. Deterioration will continue unabated unless prevention measures are applied on the headwater areas.

44. Critical areas.--Accelerated erosion has affected the watershed differently in various locations. Disturbance of the topsoil in the shallow to medium depth soils on the sloping uplands has resulted in greatly accelerated run-off, but the rate of sediment production has changed very little. Deep valley lands are slightly affected by surface removal but are severely damaged by deep gullying and bank caving that produces great quantities of sediment. In some areas lands have been damaged in equal severity by sheet and gully erosion

by reason of depletion of cover on highly erodible soils. Depositions of coarse debris carried in by floodwaters has destroyed many valuable farms in some mountain valleys. Damage by erosion is most severe in the areas immediately adjacent to the densely populated parts of the watershed above Alamogordo Reservoir, along the Rio Hondo, Rio Penasco, and Toyah Creek drainages. The less densely populated areas of the upper Delaware, parts of the Macho and Rio Felix, Alamogordo, and Black River systems are also considered critical sediment-source areas (map 18). Stream bank cutting along the Pecos River and along tributaries is extremely important because these are the highly developed agricultural areas.

LAND AND WATER ECONOMY

45. Historical development.--First Spanish settlements were in the upper watershed near Pecos, New Mexico, during the latter part of the 18th century. Hostile Indians slowed progress in the early settlement of the area. After the conclusion of the Civil War, the Army established numerous forts in the West to subdue marauding Indians. The livestock industry developed rapidly thereafter and by 1880, livestock grazing was common throughout the upper and middle portions of the basin. By 1900 the entire watershed was being used for the grazing of livestock. In addition to livestock raised in the basin, cattle from adjacent areas were trailed through the Pecos Valley northward to railroad shipping points. In some sections of New Mexico, cattle numbers reached the peak about 1885. By the turn of the century, overgrazing was general in the watershed and there was considerable evidence of erosion.

46. Various methods of disposing of land to encourage settlement were employed. They still influence social and economic problems. Grants of large tracts of land were made by Spain and Mexico to individuals and groups. These grants were recognized when the Territory of New Mexico came under the jurisdiction of the United States in 1848. Boundary disputes were settled by a Court of Claims created in 1890. Portions of grants had to be sold to pay litigation costs. Certain of these lands have been sold to pay taxes on lands retained. As a result, the grants dwindled in size while the number of people dependent upon them for a livelihood increased. This pressure contributed to the serious deterioration of land resources.

47. Settlement was also stimulated by homestead laws and grants to railroads. The various methods of acquiring titles and the policy of states and the Federal Government to withhold tracts from private ownership developed a complicated pattern of land ownership. The chief difference between Texas and New Mexico portions of the watershed

is the prevalence of large acreages of public land in New Mexico. State land makes up a small percentage of the portion of the watershed in Texas. There is no federally owned land in the Texas portion of the watershed except some small tracts used for military purposes. Irrigated farming in the basin antedates the first Spanish settlements. Spanish settlers found Indians producing crops on small tracts of irrigated land along the river. These and later settlers farmed under irrigation and it has grown to be one of the most important sources of income in the watershed.

48. Population.--The population of the watershed was about 150,000 in 1940. Of this number, 92,000 individuals resided in rural areas, and 58,000 in urban centers. New Mexico accounted for about 100,000, or 67 percent of the population, and Texas the remaining 50,000, or 33 percent. Throughout the entire watershed, population is concentrated along water courses. Only a few crossroad stores and widely scattered ranch homes are found at distances from the principal streams. Roswell is the largest city in the watershed. Its present population is nearly 20,000. Other important communities along the stream courses are Las Vegas, Santa Rosa, Carlsbad, and Artesia, New Mexico; and Pecos, Balmorhea, and Fort Stockton, Texas. Communities of Spanish speaking people are among the earliest settlements in the area. These communities are concentrated in the headwaters of the Pecos and along the upper reaches of the Rio Hondo. All of the large communities except Las Vegas, New Mexico, are subject to severe flood damage because of their close proximity to the Pecos River or to tributary streams. Also, the highly developed irrigated farms located in the vicinity of the urban settlements in the overflow areas suffer heavy damage during floods. Hence, the greatest amount of flood damage occurs in the urban communities and in the adjoining farm land. The settlements in the headwaters of the Rio Hondo and Rio Penasco sustain losses by floods because the villages and the agricultural land which supports them are located in overflow areas. Agricultural lands are damaged by flooding, erosion, and the disposition of debris that has to be removed before the land can again be used.

49. Landownership.--The pattern of landownership in New Mexico is one of private holdings scattered among state land, public domain, and national forests. National forest and Indian lands occupy high water yielding areas in the headwaters. Large areas of the Santa Fe, Cibola, and Lincoln National Forests are situated in the watershed as is a major portion of the Mescalero Apache Indian Reservation. Landholdings of the railroads are in small tracts and are scattered, except in Texas where large tracts were granted to the railroad systems by the state. Ownership of land has developed into such a mixed pattern that proper control and administration has been difficult to obtain, and widespread misuse has greatly reduced grazing resources. Landownership in the contributing watershed is distributed as follows: federally owned or administered, 18 percent; state, 18 percent; and private, 64 percent (See table 2 and map 9). The distribution of ownership in the closed basin is assumed to be the same.

Table 2 - Classes of Landownership
Pecos River Watershed

	sq. mi.	acres	Percent of Total
Federally owned or administered			
National forest	1,808	1,157,120	5.4
Public domain 1/	3,482	2,228,480	10.5
Indian 2/	460	294,400	1.4
Other 3/	130	83,200	0.4
Subtotal	5,880	3,763,200	17.7
State 4/	5,946	3,805,440	17.9
Private 5/	21,394	13,692,160	64.4
Subtotal	27,340	17,497,600	82.3
Total 6/	33,220	21,260,800	100.0

1/ Lands reserved for special purposes as federal range and unreserved and unappropriated lands administered by the Department of the Interior.

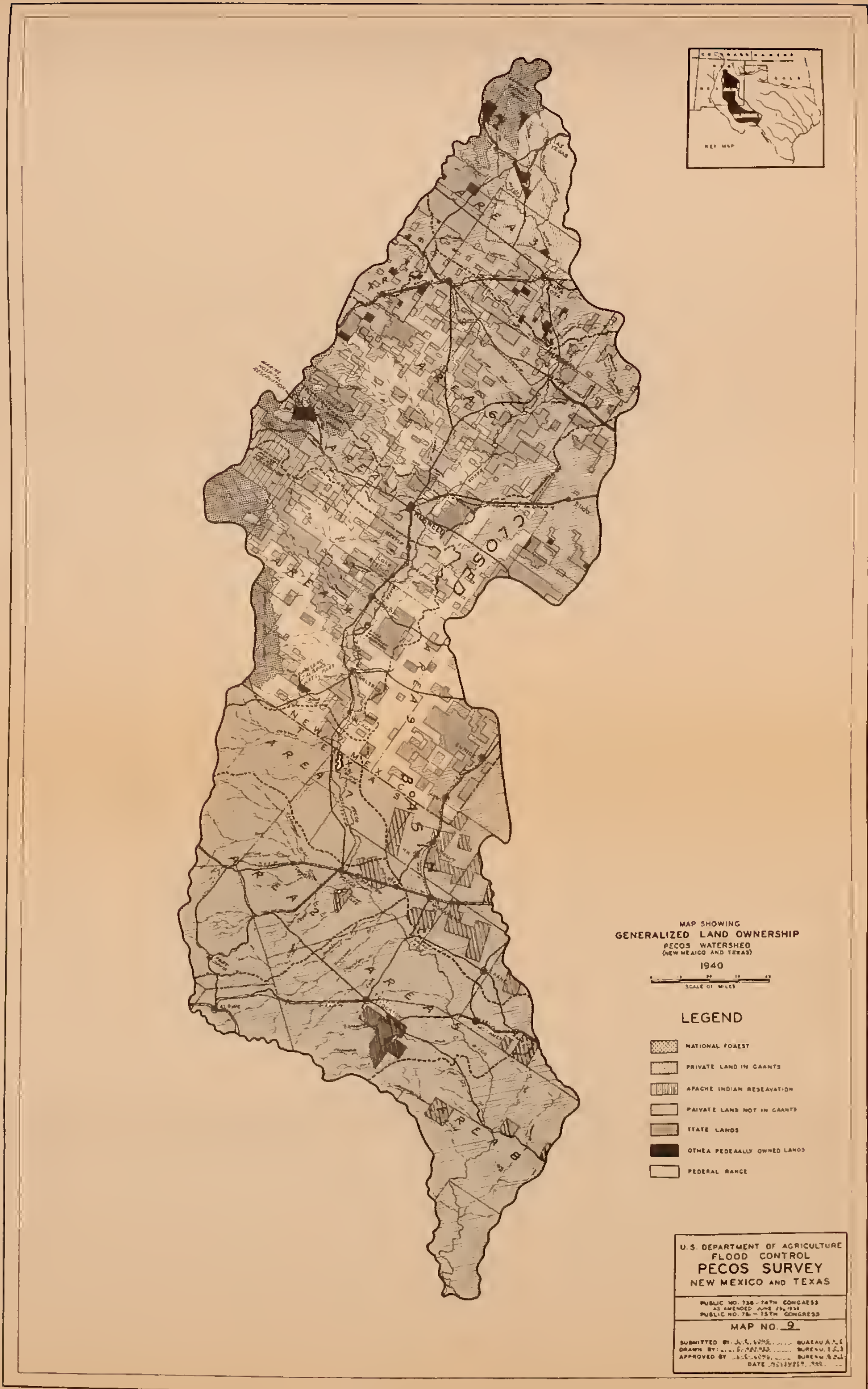
2/ Mescalero-Apache Indian Reservation, administered by the Federal Government.

3/ National parks and monuments, military and other reserves, and miscellaneous federally owned lands.

4/ School and university lands, state parks, tax forfeitures, and minor state holdings.

5/ Lands owned by individuals, communities, and corporations.

6/ Does not include areas in closed basins.


MAP SHOWING
GENERALIZED LAND OWNERSHIP
PECOS WATERSHED
(NEW MEXICO AND TEXAS)
1940
SCALE OF MILES
LEGEND
NATIONAL FOREST
PRIVATE LAND IN GRANTS
APACHE INDIAN RESERVATION
PRIVATE LAND NOT IN GRANTS
STATE LANDS
OTHER FEDERALLY OWNED LANDS
FEDERAL RANGE
U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL
PECOS SURVEY
NEW MEXICO AND TEXAS
PUBLIC NO. 738 - 74TH CONGRESS
AS AMENDED
PUBLIC NO. - 75TH CONGRESS
MAP NO. 9
SUBMITTED BY
DRAWN BY
APPROVED BY
DATE
KEY MAP
NEW MEXICO
AREA

Land Use

50. The direct drainage portion of the watershed comprises about 21,260,000 acres, which is classified as follows: grazing land, 20,700,000 acres; cropland 385,000 acres; and nonagricultural land, 175,800 acres. In this classification, timber and woodland areas of the watershed are included as grazing land since all such lands are used for grazing as well as a source of lumber, posts, and firewood. Grazing lands, therefore, comprise 98 percent of the watershed. The following discussion pertains to the watershed exclusive of closed basins (pars. 51-60).

51. Range.--The major part of the watershed area is occupied by range land. Yearlong grazing is practiced on the majority of these lands. Native vegetation has deteriorated in varying degrees throughout the area. Deterioration of the vegetative cover is most pronounced on critical sediment source areas (map 17). On these depleted areas run-off is abnormally high and erosion is active. Range deterioration is especially critical on areas adjacent to small villages in the portion of the watershed above Alamogordo Reservoir. The gross value of ranch products marketed in 1948 is estimated at $30,000,000.

52. Timberland.--There are about a million acres of timber land in the watershed (map 8), most of which are in national forests. During 1948 approximately 28 million board-feet of timber were harvested. The average price of this lumber at the mill was not less than $40 per thousand, making a total value of $1,120,000. Considerable income was derived from the sale of wood products for ties and mine props. About 1.7 million board feet of timber were harvested and made into these items. Calculated on the same basis as lumber, they were worth $68,000. About 69 percent of the area of coniferous saw timber is in national forests, 19 percent in the Mescalero-Apache Indian Reservation, and 12 percent on state and private land. The areas in forests are the main irrigation-water yielding portion of the watershed. The national forests are situated in the headwaters, which are the main water supply tributaries of the Pecos. The forests are reservoirs where water is stored for irrigation farming downstream. The agricultural interests downstream depend upon the watershed for an adequate supply of water. The average annual water yield from the Santa Fe National Forest is 270 acre-feet per square mile. The areas of the forest which yield the greatest amount of water are the upper portions of the Pecos and Gallinas Rivers. The annual yield of these areas is about 400 acre-feet per square mile. It is estimated that the higher elevations of the Lincoln National Forest yield annually 300 acre-feet per square mile. The average annual yield of the portion of the Lincoln National Forest within the Pecos watershed is estimated to be 100 acre-feet per square mile.

It is estimated that the annual water yield from adjacent woodland and grassland areas located at lower elevations is 40 acre-feet per square mile. The yield from the more arid portion of the watershed is probably as low as 3 acre-feet per square mile. This comparison of water yields from the various parts of the watershed emphasizes the importance of the forests as reservoirs to store water for irrigation. Other important uses of the forests are livestock grazing and recreation.

53. Woodland.--Slightly more than three million acres of the watershed are classified as woodland (map 8). Approximately 50,000 cords of firewood were cut from these lands in 1948. The value of this product was about $375,000. The value of fence posts taken from woodland areas has not been estimated. Woodland areas are also used for grazing and recreational purposes.

54. Cultivated land (irrigated).--Approximately 275,000 acres in the watershed are irrigated (map 8). About 60 percent is irrigated with water from wells and springs. The largest area is located in the vicinity of Roswell and Artesia, New Mexico. Other areas irrigated by wells and springs are located at Balmorhea and Fort Stockton, Texas. Major irrigation developments dependent upon storage reservoirs are the Storrie project at Las Vegas, the Carlsbad project in New Mexico, which is served by Alamogordo, McMillan, and Avalon Reservoirs, and seven water improvement districts in Texas served by the Red Bluff Reservoir. Storage facilities are not available in many of the small valleys in the upper reaches of the watershed. Irrigation by small diversions from stream channels is the common method of watering crops. Typical of such areas are Pecos River and its tributaries above Alamogordo Reservoir, upper Rio Hondo and its tributaries, and upper Rio Penasco and its tributaries.

55. Farms in the upper valleys average less than 15 acres; subsistence farming predominates. Farms are larger in the other irrigated sections of the watershed where farming operations are more diversified and better developed. Farms in the Carlsbad project average about 60 acres and units in the Roswell-Artesia section and in the Pecos Valley below Red Bluff Reservoir are larger. Important crops produced on the larger farms include alfalfa, cotton, and sorghum. The gross value of farm products marketed in 1948, produced on irrigated farms, is estimated at $26,000,000.

56. Certain irrigated farm lands, especially those situated in tributary areas, are subject to flood damage but are not major flood source areas. However, run-off from large continuous areas of irrigated lands such as those at Roswell and Artesia, New Mexico contributes to flood flows during major storms. Irrigated lands

are a source of sediment. Stream bank erosion along the main river and tributary drainages which cross irrigated lands produces sediment which is eventually carried into reservoirs and irrigation systems. In some areas, waste water from irrigated lands pouring over cut banks into the streams causes soil to slough off into the channels. This material is also carried downstream to damage irrigation facilities.

57. Cultivated land (dry farm). Dry-farm operations are confined to about 110,000 acres, most of which are in the watershed area above Alamogordo Reservoir. Crop production on these lands is marginal because of limited moisture. Beans, corn, and wheat are produced on dry-farm lands. The gross value of farm products produced on dry-farm lands in the watershed during 1948 is estimated at $2,200,000.

58. Dry-farm lands, although comprising only about 1 percent of the watershed, are sources of abnormally high run-off and large quantities of sediment. In general dry-farm tracts are small and intermingled with deteriorated range lands. Little progress has been made in getting operators of dry farms to adopt conservation practices which will retard run-off and reduce sediment. Most of the operators are subsistence farmers and will need financial help in applying the conservation measures needed to accomplish this.

59. Recreational use.--There are many recreational attractions in the watershed. These include notably the high, scenic mountain areas near the headwaters and along the western flanks of the basin, especially in New Mexico. Many camp sites and recreational areas have been developed in the national forests. Carlsbad Caverns National Park, administered by the National Park Service, is in the mid-basin in New Mexico, and there are two state parks, Bottomless Lakes, near Roswell, New Mexico, and Balmorhea in Texas. Considerable recreational use is made of the Alamogordo, Avalon, and Red Bluff reservoirs. The region is rich in historic interest, with remains of several frontier Army posts, and there is significant archeological evidence of long prehistoric occupation and use.

60. Other resources and developments.--The mining of potash near Carlsbad is an important industry in the watershed. Oil and gas production east of the Pecos River in the Texas portion of the watershed contributes materially to the economy of the area. The watershed is served by an extensive network of highways, farm to market and forest roads, and railroads (map 1).

PAST AND CURRENT ACTIVITIES RELATED TO FLOOD CONTROL

General

61. No over-all approach has been made to alleviate flood damages. Alamogordo and Red Bluff Reservoirs on the Pecos River have a regulating effect below their respective locations. Alleviation of flood damage by these reservoirs, although material, is incidental to their operation for irrigation purposes. No storage is set aside in either reservoir for flood control, and the degree of protection which they afford is erratic. When floods occur, neither reservoir may be in a position to impound sufficient water to have a regulatory effect.

Activities of Federal Agencies

62. Department of the Army, Corps of Engineers.--The Corps of Engineers is conducting a flood control survey in the watershed. Detailed studies are being made of floodwater damages along the main stream and in the vicinity of Roswell and Carlsbad, New Mexico, and Pecos, Texas. Works of improvement in the following tributaries to alleviate floodwater damages in the aforementioned localities are being investigated by the Corps of Engineers at the present time: Rio Hondo and Dark Canyon in New Mexico and Salt Draw and Cottonwood Creek in Texas. Accordingly, floodwater damages have not been considered in these localities in preparing this report nor has the program herein recommended been evaluated with respect to reduction in floodwater damages in these localities. Works of improvement involving floodwater detention installed in the future by the Corps of Engineers will have their useful life extended as the recommended program lowers the sediment production rate in the watershed. These additional benefits have not been evaluated in this report.

63. Department of Agriculture, Forest Service.--Lands within the boundaries of the Santa Fe and Lincoln National Forests are important water-storage areas in the headwaters. A relatively small area of the Cibola National Forest is also within the basin (map 1). Forest Service policy is to have these lands serve multiple uses. Among the important uses are watershed protection, timber and forage production, and recreation. Preservation or restoration of satisfactory watersheds is a primary objective of the Forest Service program. The major current activities toward the accomplishment of this objective are protection from fire, and grazing and timber management. The result of these activities, or improved watershed conditions, contributes materially toward water-flow retardation and soil erosion prevention. The current Federal cost of this work and of other related measures which are being installed in the aid of flood and sediment reduction is about $81,600 annually.

64. Department of Agriculture, Soil Conservation Service.--The Soil Conservation Service is assisting 25 soil conservation districts in the direct drainage portion of the area with their conservation problems in the watershed (map 10). This involves the planning and application of a soil and water conservation program on private and state lands in the watershed. Certain measures installed under this program, such as terracing, stock water developments, diversion structures, etc., materially contribute to the reduction of floods and sediment production. The current Federal cost of technical assistance furnished by the Soil Conservation Service in furthering such activities is estimated at $133,000 annually.

65. Department of Agriculture, Production and Marketing Administration.--The Production and Marketing Administration is assisting farmers and ranchers with the installation of conservation measures through the agricultural conservation program. It offers financial assistance to individuals who cooperate in the conservation program by carrying out approved soil and water conservation practices. Many of these practices are in the aid of water flow retardation and sediment reduction. Certain of these measures, such as terracing, reseeding, and stock water developments, are similar to those in the proposed remedial program. The current Federal cost of direct aids to farmers and ranchers for installing such measures within the watershed is about $182,000 annually.

66. Department of Agriculture, Extension Service.--The Extension Service through its normal educational activities is assisting with the application of conservation measures within the Pecos River watershed. Such activities as direct contacts with individuals and groups, farm and ranch demonstrations, and the distribution of publications are used to acquaint farmers and ranchers with the need and purpose of conservation work within the watershed. Included in this information is that which pertains to numerous practices which, when installed, are of direct aid in the reduction of flood flows and sediment production. Although the amount of time devoted to such activities by individual Extension Service employees is small in comparison with that required by their many other duties, the combined activities of county agents, specialists, and state office personnel are of considerable importance. The current Federal cost of these educational activities in the aid of flood water and sediment reduction is estimated at $17,000 annually.

67. Department of Agriculture, Farmers Home Administration.--The Farmers Home Administration assists farmers and ranchers with their conservation problems as well as with other farm and ranch improvements. Financial and technical assistance through the loan program is provided to install or rehabilitate irrigation systems, construct stock water developments, fencing, soil stabilizing measures, and other range improvements. In addition,

services rendered by this agency provide for such measures as adjustment in livestock numbers to forage production and pasture rotation to allow for reseeding. Many of these practices and measures contribute materially to the reduction of floodwater and sediment production within the watershed. Federal funds loaned to farmers and ranchers by this agency are repaid and consequently only administrative costs to the Federal Government are involved. Since the proportion of administrative costs that contribute to flood and sediment retardation is relatively small, no monetary evaluation of these costs has been attempted.

68. Department of the Interior, Bureau of Land Management.--The Bureau of Land Management administers more than 2 million acres of public domain grazing land within the Pecos River watershed in New Mexico, pursuant to the Taylor Grazing Act of 1934. (There exists no public domain in the State of Texas.) Most of this public domain lies within an established Grazing District, headquarters Roswell. The bulk of the remainder occurs in widely dispersed pattern in the watershed above Ft. Sumner. BLM's contribution to land and water conservation on the watershed consists principally of improved range management. However, in addition, it controls range fires, installs needed range improvements and carried on a limited amount of strictly soil and moisture conservation operations. (The two last-mentioned items have been financed at an annual cost of approximately $17,000 of Government funds.) All of the foregoing either directly or indirectly improve watershed conditions and aid in flood control.

69. Department of the Interior, Bureau of Indian Affairs.--The Mescalero Apache Indian Reservation is located in the headwaters of the Rio Ruidoso, Rio Felix, and Rio Penasco drainages (map 1). Approximately 290,000 acres of range land and 1,500 acres of cultivated land comprise the land use on the reservation. Although certain measures, such as stockwater developments, terraces, etc., have been installed on these lands, the primary efforts and expenditures have been directed toward proper stocking and good timber management. Both of these activities are, of course, of importance in the establishment and maintenance of good watershed conditions and resultant reduction in floods and sediment. The current Federal cost of services provided by the Bureau of Indian Affairs in the aid of floodwater and sediment reduction is about $24,000 annually.

70. Department of the Interior, Bureau of Reclamation.--A soil and moisture conservation program of gully control and sediment detention is being carried out by the Bureau of Reclamation on lands administered by that Agency above the Alamogordo Reservoir. This work is being integrated with other conservation measures including revegetation and improved management of grazing lands. The program on Federal land is being integrated with plans for similar work on privately owned land.

Technical services for the development of the program is being supplied by the Soil Conservation Service through a cooperative agreement between the Bureau of Reclamation and Soil Conservation Service.

The construction work and application of other practices is being accomplished through a similar agreement with the DeBaca County Soil Conservation District.

The current annual Federal cost of the program amounts to about $13,000. The current rate of application of the program appears to be adequate to satisfy needs on lands administered by the Bureau of Reclamation during a 15-year period.

In cooperation with the Carlsbad Irrigation District the Bureau of Reclamation is carrying out a soil and moisture conservation project above McMillan Reservoir the objectives of which are: (1) to determine the most effective means of reducing non-beneficial consumptive use of water in the McMillan Reservoir delta area, conveying flood flow through the salt cedar infested sediment beds, and rehabilitating the land to an economical form of land use; (2) to determine the water savings obtained as a result of the construction of a channel through the delta area by the Carlsbad Irrigation District and through salt cedar eradication; (3) to determine the annual rate of sediment deposition in the McMillan Reservoir and delta area under present conditions with Alamogordo Reservoir in operation; and (4) to collect and assemble data that will be valuable in carrying out water conservation programs in other similar areas.

Investigations completed thus far include the spraying of selected areas of adult salt cedars with 2-4-D chemical sprays and observing the results obtained. Other tests are in progress to devise the most efficient and economical method of chemical control. A small tract has been cleared with machinery, rough leveled and will be planted to various salt resistant types of range grasses. Means for determining the water savings are being installed and plans for management of the delta area are being formulated.

The annual Federal cost of investigations being made to determine the most practical and economical way of eradicating and controlling salt cedar growth on the delta area above McMillan Reservoir amounts to about $20,000.

In addition to the foregoing work in progress in the basin, plans have been developed for the construction of a conveyance channel around the salt cedar area to reduce transmission losses of water at this point.

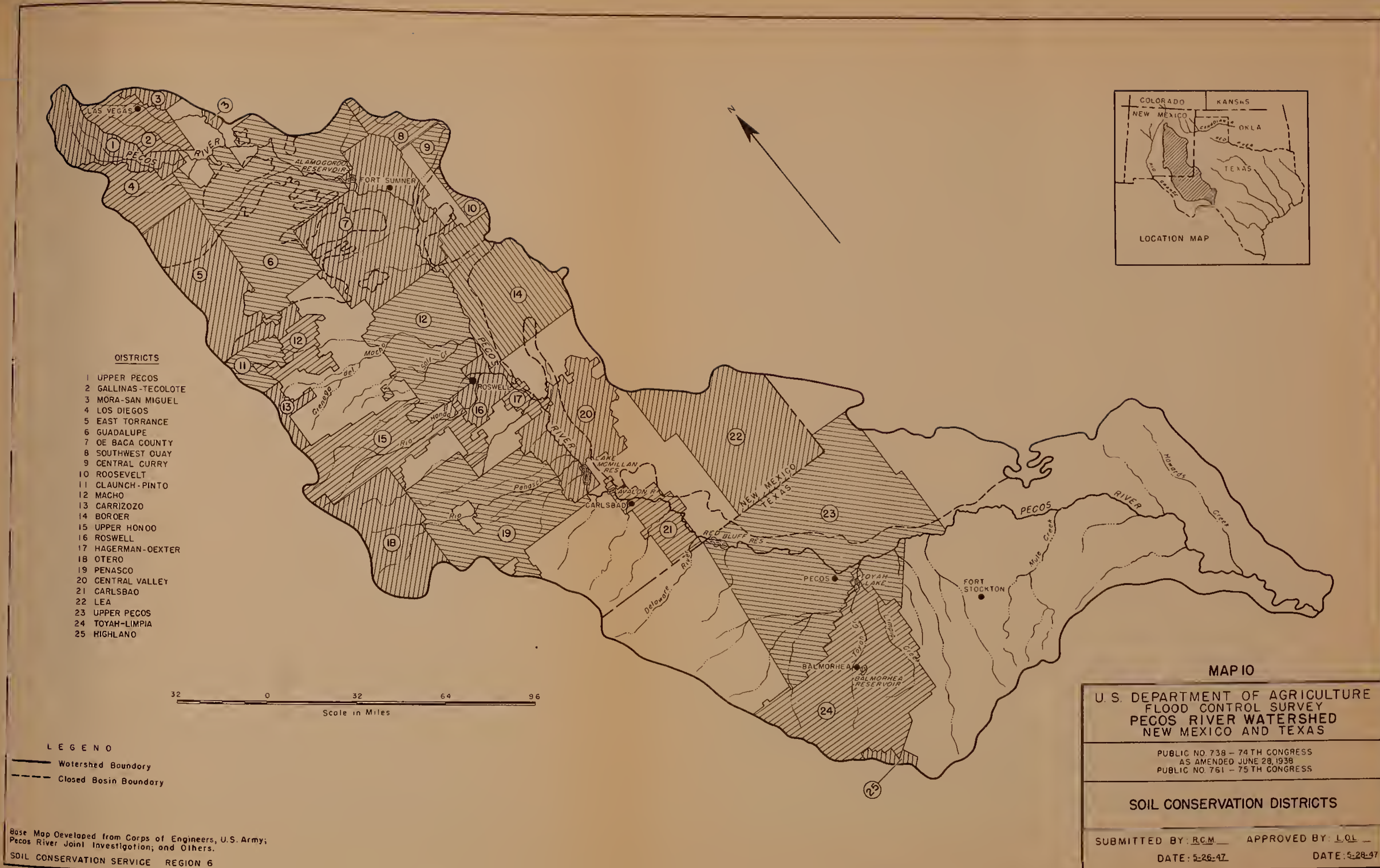
71. Department of the Interior, Fish and Wildlife Service.--The Fish and Wildlife Service has the responsibility for directing predator and rodent control work in the watershed in cooperation with appropriate state and local agencies. The costs of these activities are estimated at $50,000 and $3,000 respectively. The Service administers the Santa Rosa and Dexter fish cultural stations in the Pecos River Watershed in New Mexico. It also operates the Bitter Lakes national wildlife refuge, an area of 27,700 acres near Roswell. Studies are conducted by the Service to determine the effect of water resources projects on fish and wildlife resources. The rodent control work improves watershed conditions which affect the amount of floodwater and sediment from the areas protected.

72. Department of the Interior, National Park Service.--The Carlsbad Caverns National Park which is administered by the National Park Service has a land area of 49,742 acres. The Park is located in Eddy County, New Mexico, within the Pecos River Watershed. This area of the watershed is considered to be moderately eroded and management practices to aid in retarding runoff and stabilizing erosion are being carried out. Other soil conservation measures planned for this area are range re-seeding and sediment control structures estimated to cost $6500.

Other Activities

73. Soil Conservation Districts.--There are 25 soil conservation districts operating within the direct drainage portion of the watershed (map 10). Many of the districts have recognized flood and sediment problems in developing their programs and work plans. As a result, much of the work accomplished is directed toward the objectives outlined in the remedial program. The districts have been operating only a comparatively short time and with limited resources, however, and the work accomplished thus far has not materially affected the flood and sediment problems in the watershed as a whole.

74. City of Roswell, New Mexico and City of Pecos, Texas have constructed some flood protection works. At Roswell, New Mexico, a flood channel has been constructed through the upper section of the city. With a capacity of about 2000 cubic feet per second, it is designed to carry floodwater from the Rio Hondo through the urban area. Other installations include small diversions and dikes on the flood plain of the Rio Hondo. These projects have been of value, but city officials recognize that the work is neither of sufficient size nor scope to provide adequate protection from jajor floods. At Pecos, Texas small channels have been constructed to divert floodwater from the urban area. These channels will only handle small flows and the outlets do not satisfactorily provide for the disposal of excessive runoff.


MAP 10
U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS
PUBLIC NO. 738 – 74TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 – 75TH CONGRESS
SOIL CONSERVATION DISTRICTS
SUBMITTED BY: R.C.M.
APPROVED BY: L.O.L.
DATE: 5-26-47
DATE: 5-28-47
DISTRICTS
1 UPPER PECOS
2 GALLINAS-TECOLOTE
3 MORA-SAN MIGUEL
4 LOS DIEGOS
5 EAST TORRANCE
6 GUADALUPE
7 DE BACA COUNTY
8 SOUTHWEST QUAY
9 CENTRAL CURRY
10 ROOSEVELT
11 CLAUNCH-PINTO
12 MACHO
13 CARRIZOZO
14 BORDER
15 UPPER HONDO
16 ROSWELL
17 HAGERMAN-DEXTER
18 OTERO
19 PENASCO
20 CENTRAL VALLEY
21 CARLSBAD
22 LEA
23 UPPER PECOS
24 TOYAH-LIMPIA
25 HIGHLAND
LEGEND
Watershed Boundary
Closed Basin Boundary
32 0 32 64 96
Scale in Miles
Base Map Developed from Corps of Engineers, U.S. Army; Pecos River Joint Investigation; and Others.
SOIL CONSERVATION SERVICE REGION 6
LOCATION MAP
COLORADO
KANSAS
NEW MEXICO
OKLA
TEXAS
N
LAS VEGAS
PECOS
RIVER
ALAMOGORDO RESERVOIR
FORT SUMNER
ROSWELL
LAKE McMILLAN RES
AVALON RES
CARLSBAD
RED BLUFF RES
NEW MEXICO
TEXAS
PECOS
TOYAH LAKE
BALMORHEA
BALMORHEA RESERVOIR
FORT STOCKTON
PECOS RIVER
Delaware River
Mule Creek
Howards Creek
Rio Penasco
Rio Hondo

6-P-12998-C

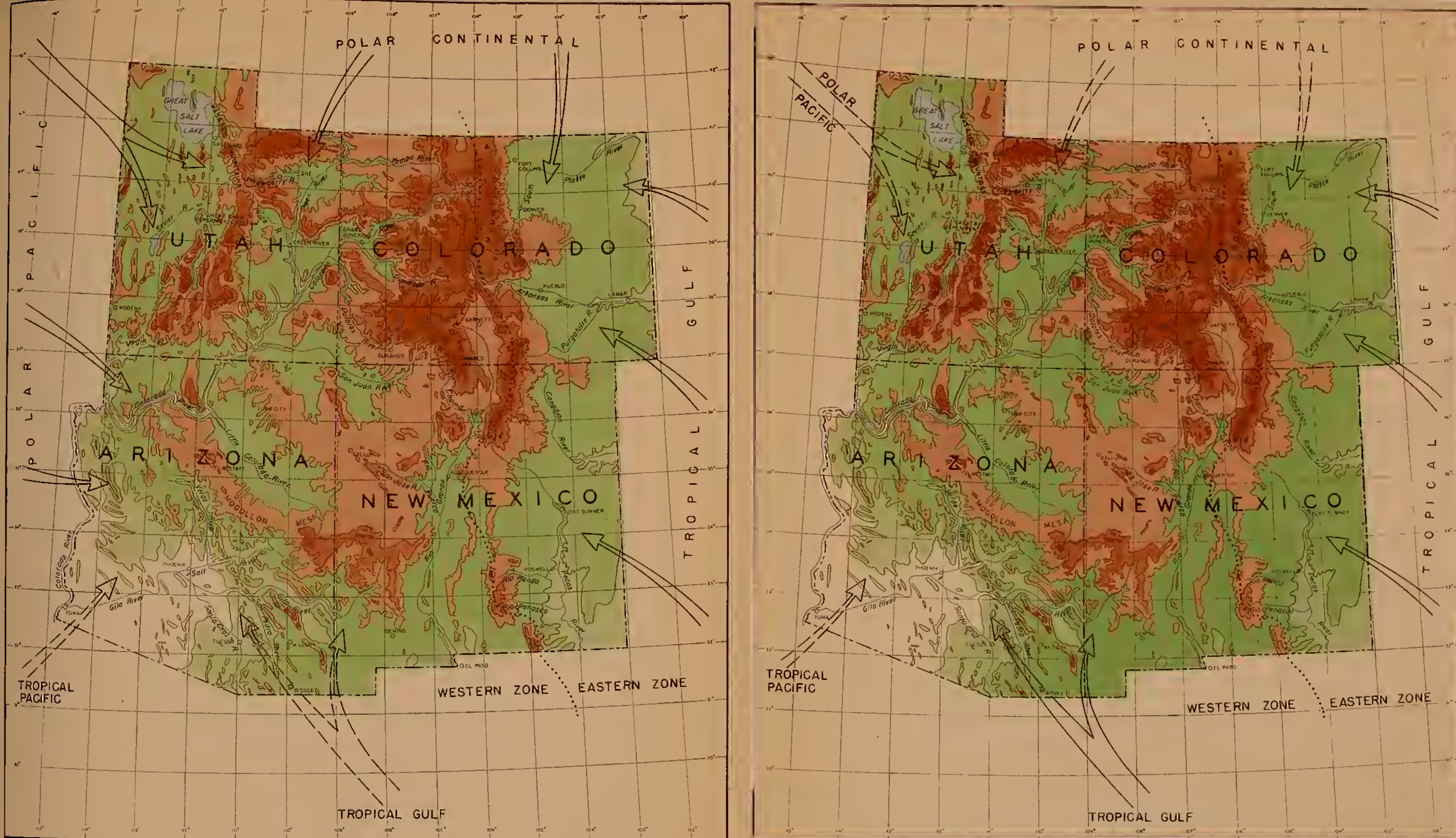
HYDROLOGY

Precipitation

75. Source and distribution.--The primary sources of precipitation in the Pecos Basin are the Gulf of Mexico-Carribean and the Pacific Ocean. During the winter months, the Aleutian low pressure area moves southeastward and becomes the source of the majority of moisture brought to the western states. At this time the general upper air circulation is not conducive to invasions of air masses from the Gulf of Mexico and Carribean. Because of the Rocky Mountain barrier, the invasions of Pacific air may cause considerable cloudiness without producing significant amounts of precipitation. The winter months, therefore, are the driest of the year. During summer with the development of the North American High Level Anticyclone, large masses of moist air may move in from the Gulf of Mexico or Carribean. As a result, the precipitation during this period is greater than at any other time of the year. The Aleutian Low Pressure area may meanwhile move far northward and exert little influence on the climate of the Pecos Basin. Spring and fall months are transitory periods during which invasions of either air mass may occur. Ordinarily the months become increasingly wetter as summer is approached and Gulf-Carribean air masses invade more frequently. The trend is downward during the fall months due to decreasing invasions of those air masses. Figure 4 shows the direction of normal air mass movements. 1/

76. Average Annual.--The great range in elevation within the watershed of from 1,000 to over 13,000 feet above sea level and the location of various parts of the area with respect to moisture sources result not only in considerable difference in extremes of precipitation but also in a rather erratic pattern insofar as average annual totals are concerned. Map 11 shows, for example, that an area in the lower middle Pecos Basin receives less precipitation annually than is normally received by any other portion of the watershed not excepting the areas at lower elevations. This can easily be understood if it is considered that the lower portions of the watershed are progressively nearer the Gulf of Mexico. Further reference to map 11 will show the marked influence of the mountain masses such as those in the extreme upper Pecos watershed.

1/ Certain Hydrologic and Climatic Characteristics of the Southwest. University of New Mexico Press. 1946.



WINTER SUMMER

NORMAL AIR MASS MOVEMENTS

Predominating
Occasional
Zone Boundary

Reference
10000 ft.
8000 ft.
6000 ft.
4000 ft.
2000 ft.

FIG. 4

SOIL CONSERVATION SERVICE — SOUTHWEST REGION — U.S. DEPARTMENT OF AGRICULTURE

AVERAGE ANNUAL PRECIPITATION
(COURTESY PECOS RIVER JOINT INVESTIGATION)
DATA FROM U.S. WEATHER BUREAU

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL
PECOS SURVEY
NEW MEXICO AND TEXAS

PUBLIC NO. 738 - 74TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 - 75TH CONGRESS

MAP NO. 11

SUBMITTED BY: [illegible] BUREAU A.C.A.
DRAWN BY: [illegible] BUREAU [illegible]
APPROVED BY [illegible] BUREAU A.C.A.
DATE DEC. 12, 1942

N-10028

Storm Types

77. General.--There are three distinct storm types characteristic to the Pecos Basin. For discussion in this report, they are termed "localized convective," "general summer," and "general winter."

78. Localized convective.--The localized convective storm occurs only during warm weather and ordinarily is very limited in both extent and duration, although accompanying intensities are often the highest of any type. Individual storms of this type are of no importance in the consideration of floods from large segments of the watershed. These storms are of utmost importance, however, in the production of floods from subwatersheds of less than 100 square miles in area. Their short duration requires recording rain gauge records for analysis and very few stations supplying this type of information have been operating in the watershed for any length of time. In order to provide an idea of the amount of rainfall that might occur during a one-hour period in such storms, the approximate total rainfall for one hour that might occur at Roswell, New Mexico, and Amarillo, Texas, once in 10, 25, 50, and 100 years is shown in table 3. 1/

Table 3 - FREQUENCY MAGNITUDE OF PRECIPITATION

Pecos River Watershed

Station	One-hour rainfalls which probably will be equalled or exceeded once in: 10 yrs.	25 yrs.	50 yrs.	100 yrs.
Amarillo, Texas	1.90	2.20	2.70	3.20
Roswell, New Mexico	1.65	1.90	2.35	2.85

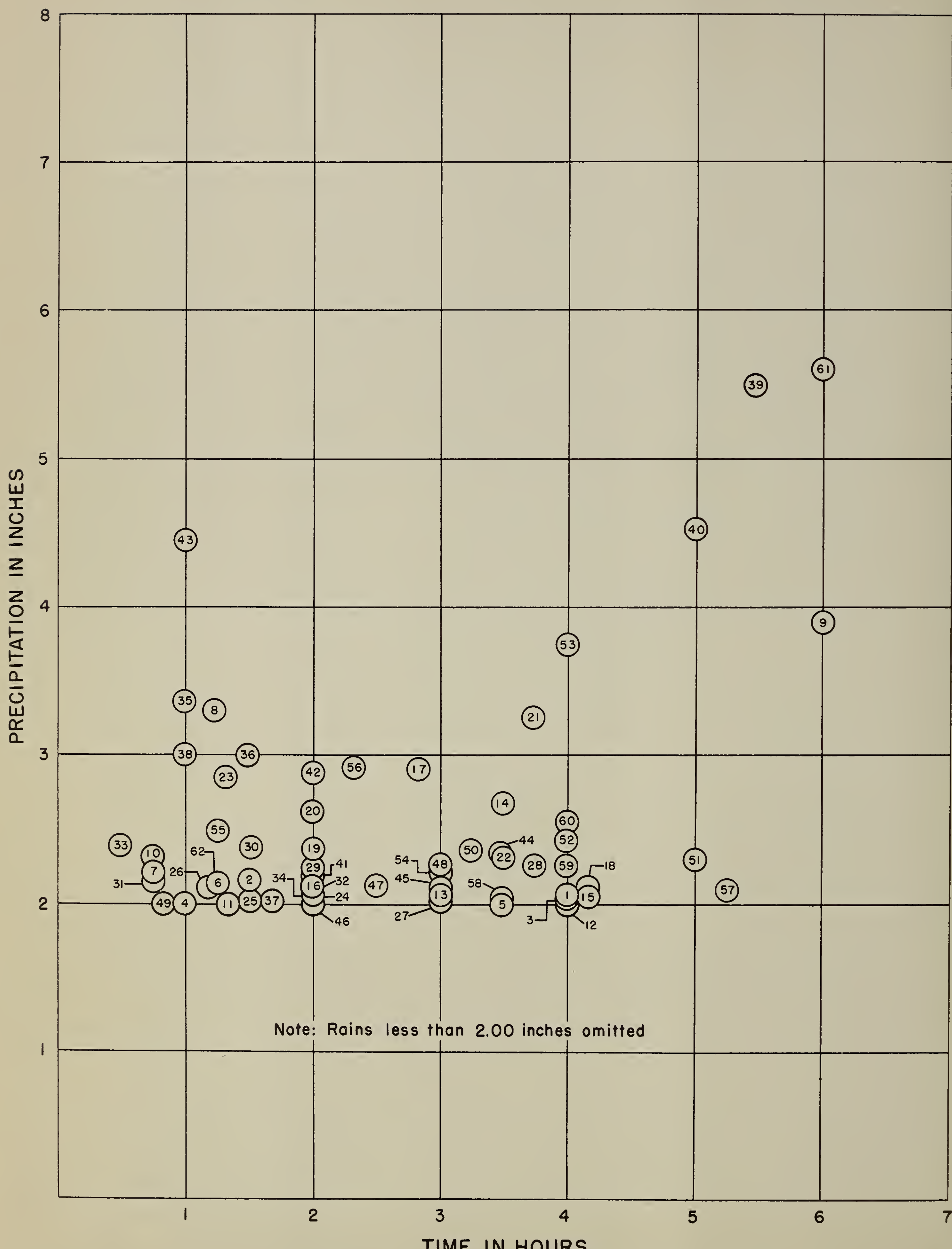
Although these data are believed to be reasonably accurate, they should not be considered as maxima since much greater one-hour intensities have been recorded in the Southwest. Examples of these rains are shown in figure 5. Many of these rains are of a magnitude

1/ Rainfall Intensity-Frequency Data. U. S. Department of Agriculture Miscellaneous Publication No. 204, 1935.

FIGURE 5

RECORDS OF EXCESSIVE PRECIPITATION

PECOS BASIN NEW MEXICO



KEY TO FIGURE 5

HARVEY UPPER RANCH
(1) Sept. 8, 1917
(2) July 27, 1919
GALLINAS PLANT STATION
(3) May 12, 1928
MINERAL HILL
(4) April 23, 1919
LAS VEGAS
(5) Sept. 11, 1912
(6) Aug. 7, 1919
PASTURA
(7) Aug. 11, 1933
SANTA ROSA
(8) May 30, 1930
CUERVO
(9) May 14, 1921
(10) July 20, 1921
(11) July 21, 1926
(12) April 5, 1939
VAUGHN
(13) May 23, 1921
FT SUMNER
(14) Aug. 13, 1908
DURAN
(15) July 27, 1927
TORRANCE
(16) June 20, 1913
(17) Oct. 1, 1923
CORONA
(18) July 9, 1937
GALLINAS RANGER STATION
(19) May 29, 1930
BOAZ
(20) June 12, 1909
ANCHO
(21) June 26, 1937
THREE RIVERS
(22) Sept. 4, 1916
(23) Aug. 7, 1919
WHITETAIL
(24) May 26, 1937
(25) June 19, 1937
MESCALERO
(26) Aug. 28, 1923
ORO GRANDE
(27) June 28, 1920
(28) July 2, 1931
(29) Sept. 1, 1938

CLOUDCROFT
(30) July 14, 1923
(31) July 29, 1927
WEED RANGER STATION
(32) Sept. 16, 1919
ELK
(33) Aug. 3, 1906
(34) Aug. 23, 1935
HOPE
(35) Aug. 22, 1908
(36) May 5, 1919
(37) June 4, 1921
(38) June 5, 1921
ARTESIA
(39) July 24, 1911
TATUM
(40) Sept. 14, 1927
LOVINGTON
(41) Sept. 9, 1913
HOBBS
(42) Aug. 26, 1915
(43) June 7, 1918
(44) Aug. 26, 1920
PEARL (near)
(45) Aug. 16, 1916
LAKE AVALON
(46) Sept. 9, 1926
(47) Oct. 11, 1929
(48) June 3, 1930
(49) May 23, 1936
(50) June 22, 1939
CARLSBAD
(51) June 8, 1904
(52) Aug. 6, 1904
(53) July 24, 1911
(54) July 28, 1916
(55) July 30, 1916
(56) Oct. 12, 1916
(57) July 24, 1928
CARSON SEEP RANGER STATION
(58) April 29, 1915
(59) July 5, 1921
(60) July 21, 1933
(61) Aug. 8, 1925
(62) July 19, 1931

Not plotted:
ARABELA - 7.71 inches in 24 hours
Sept. 16, 1919

that will not fall in a frequency array and cannot be considered for structural design purposes unless the maximum storm is to be considered.

79. General summer.—The general summer storm is, as its name implies, also associated with warm weather. This type is characterized by heavy but ordinarily less intense rainfall over large portions of the watershed. Another characteristic is the frequent occurrence of local high intensity storms within the general storm area. Ordinarily unit runoff rates from the smaller watersheds are not exceptionally high as a result of these storms, but the combined effect of this run-off from many subareas results in the greatest floods of record on the larger tributaries and the main stem of the Pecos River. Although a certain degree of heat differential is necessary for the development of this storm type, it is not necessary that hot weather prevails when it occurs since some of the major storms have been recorded during spring and fall months. Amounts of rainfall recorded during one-day periods, although of little value in the determination of short-time intensities, are nevertheless an indication of what might be expected from the general summer storm. Examples of frequency-magnitude relationships for one-day storms are given in table 4, which follows.

Table 4 - FREQUENCY-MAGNITUDE OF PRECIPITATION FOR STATIONS IN AND NEAR PECOS RIVER WATERSHED.

Station	Elev.	Years of record used in frequency analysis	One-day rainfall which probably will be equalled or exceeded once in: 10 yrs. Summer	10 yrs. Yr.	25 years Smr	25 years Year	50 years Smr	50 years Year	100 years Smr	100 years Year
Santa Rosa	4,624	29	1.91	2.39	2.11	2.66	2.30	3.04	2.39	3.31
Roswell	3,602	23	2.18	2.31	2.52	2.60	2.97	3.04	3.32	3.33
Carlsbad	3,120	42	3.01	3.18	3.66	3.87	4.57	7.84	5.28	5.58
Ft. Davis	4,800	21	2.22	2.52	2.59	3.16	3.11	4.31	3.48	5.30

In order to attempt a determination of typical intensity characteristics for rains of various sizes, short-time recording rain gauge records were secured from 31 rain gauge stations in New Mexico and western Texas. Some 40 rains were taken from the charts and grouped in various categories of volume. Each grouping was averaged mathematically and graphically with the following results (Examples, see figures 6 and 7):

a. As would be expected, intensities of rains were progressively higher beginning with rains of 0.50 to 1.00 inch and up to rains of 1.50 to 2.00 inches. Rains of from 2.00 to 2.50 inches and over showed a tendency toward lower intensities.

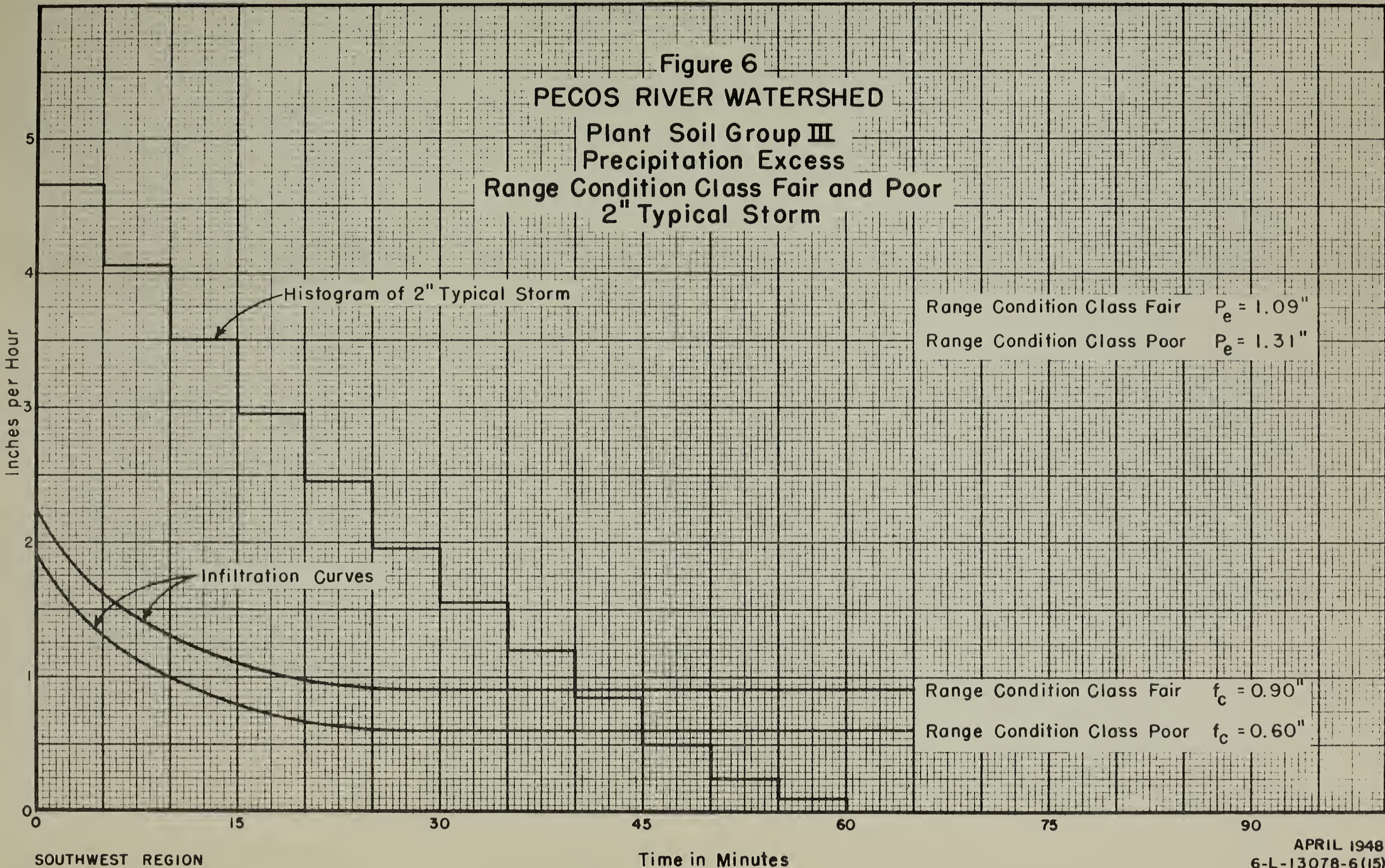
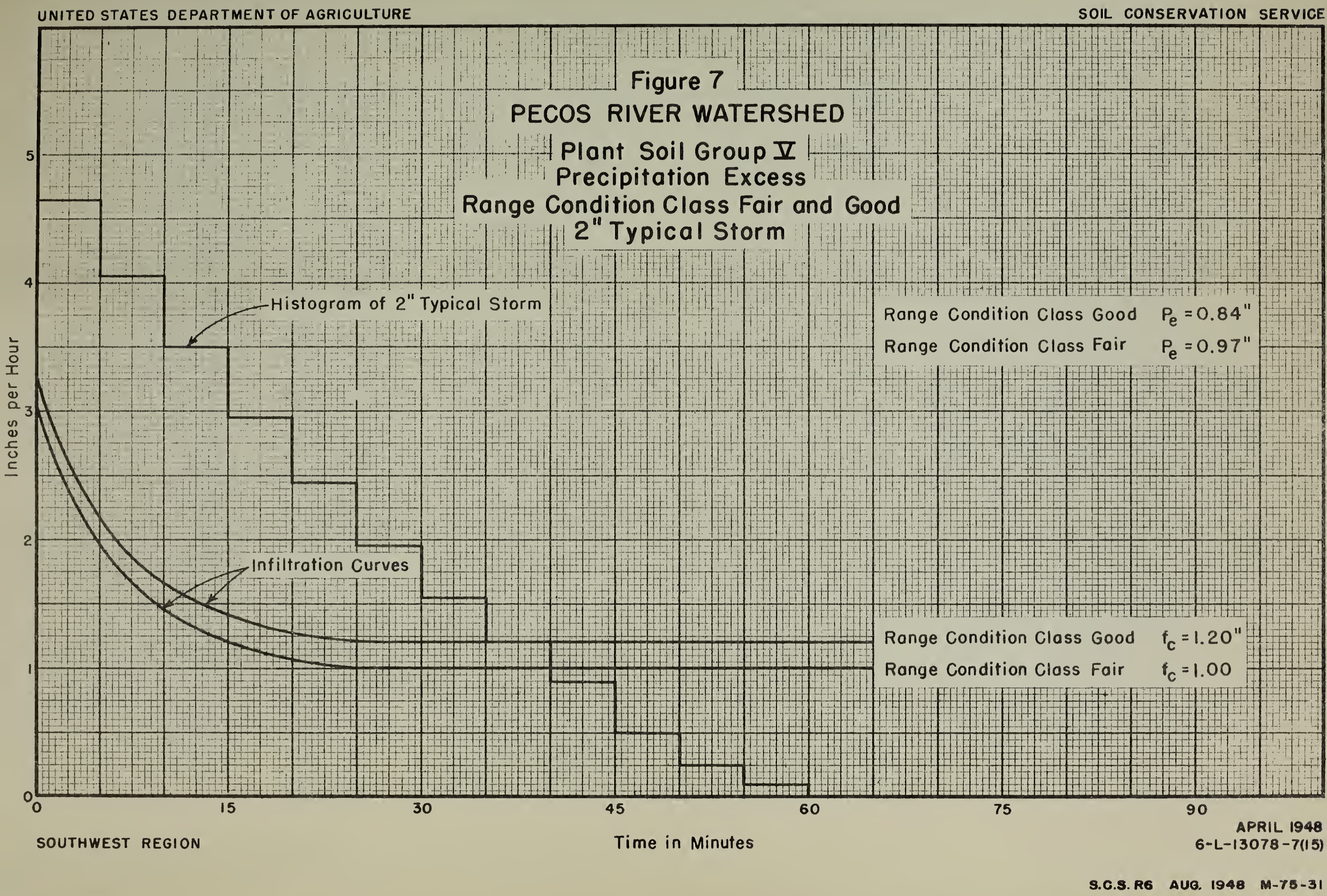


Figure 6
PECOS RIVER WATERSHED
Plant Soil Group III
Precipitation Excess
Range Condition Class Fair and Poor
2" Typical Storm
Histogram of 2" Typical Storm
Infiltration Curves
Range Condition Class Fair P_e = 1.09"
Range Condition Class Poor P_e = 1.31"
Range Condition Class Fair f_c = 0.90"
Range Condition Class Poor f_c = 0.60"
Inches per Hour
0
1
2
3
4
5
15
30
45
60
75
90
Time in Minutes


UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Figure 7
PECOS RIVER WATERSHED
Plant Soil Group V
Precipitation Excess
Range Condition Class Fair and Good
2" Typical Storm
Histogram of 2" Typical Storm
Infiltration Curves
Range Condition Class Good $P_e = 0.84"$
Range Condition Class Fair $P_e = 0.97"$
Range Condition Class Good $f_c = 1.20"$
Range Condition Class Fair $f_c = 1.00$
Inches per Hour
0
1
2
3
4
5
0
15
30
45
60
75
90
Time in Minutes
SOUTHWEST REGION
APRIL 1948
6-L-13078-7(15)
S.C.S. R6 AUG. 1948 M-75-31

b. The maximum intensities of rainfall during the storm period occurred within five or ten minutes of the beginning of rainfall for rains up to the 1.50 to 2.00-inch category with the intensities decreasing as the storm progressed. Rains in the 2.00-inch plus class, however, showed a peak intensity averaging some 15 minutes after the beginning of rainfall. The largest rains, 5-inch and over, had almost no uniformity and ordinarily were composed of several "blocks" of precipitation, which were in more or less conformity with the individual composite rains although they were generally somewhat less intense.

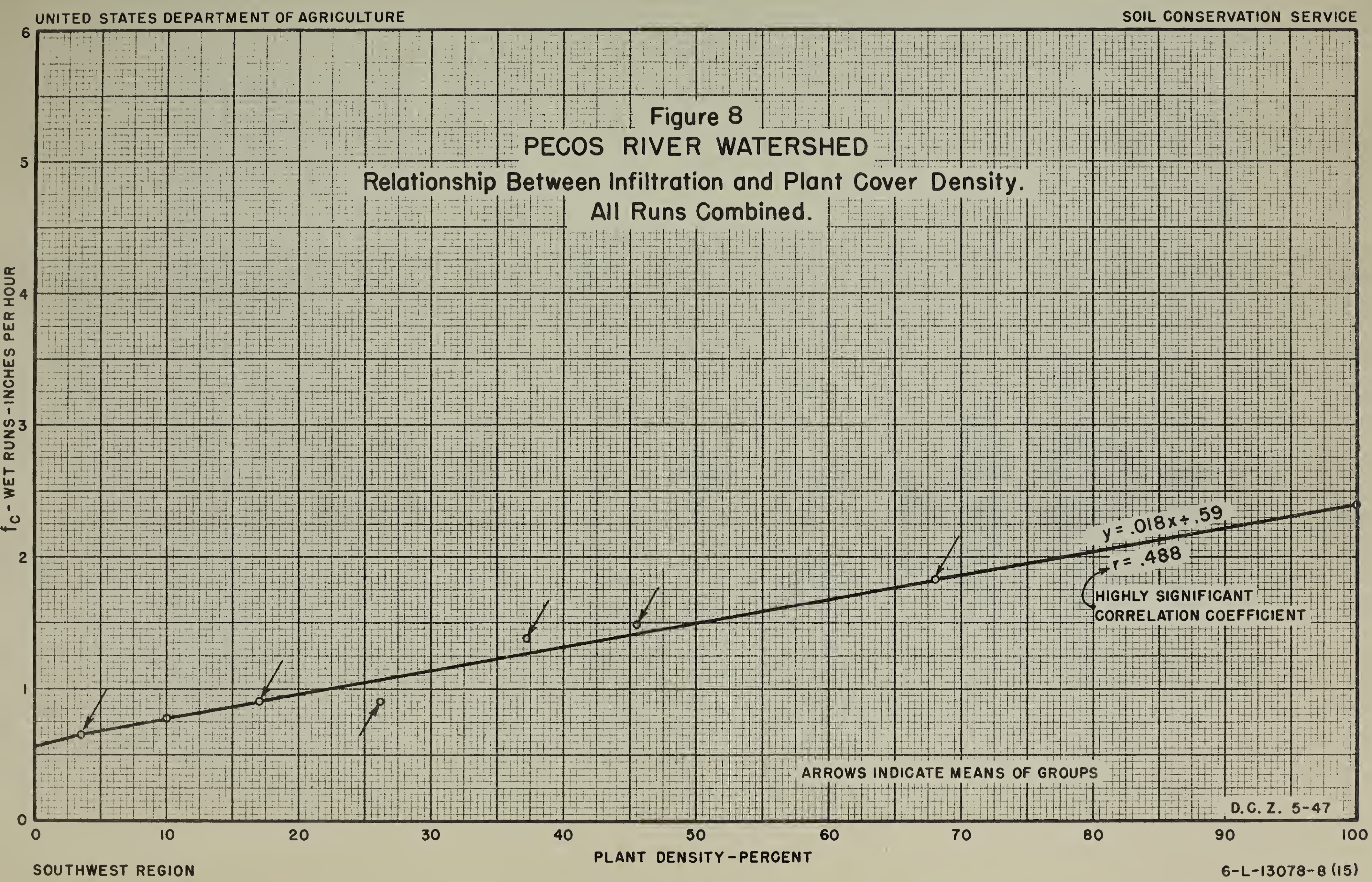
80. General winter.--The third storm type, "general winter," is important only as it has its place in the climatology of the Pecos Basin. The absence of significant heat differentials and of air containing large quantities of moisture during the winter months almost preclude the occurrence of rainfall either of high intensity or amounts. This type, therefore, is characterized by intermittent low intensity rains frequently of several days duration and is of little consequence in the consideration of flood flows.

Infiltration Analysis

81. Infiltration related to plant-soil groups.--Some 260 infiltration runs were made on the Pecos River watershed during 1940, using the FA type infiltrometer. Wet runs were made under different conditions of soils and vegetation. An analysis indicated a relationship between plant cover density and the final infiltration rate. The analysis has been substantiated by grouping all of the runs according to different plant cover densities. The correlation was determined to be "highly significant" and is illustrated in figure 8.

82. Using this over-all relationship as a basis, a procedure was developed to determine the influence of changes in plant cover on the infiltration rate under present conditions and conditions that might be expected with a program. Once this had been accomplished, the amount of precipitation excess for different storm types could be determined.

83. It was found that the 260 infiltration runs could be grouped according to seven broad groups of soils and vegetation and that each group could be analyzed separately. The plant-soil groups established are as follows:



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Plant-Soil Group

I. Desert grassland on all soils of varying depths and textures.

II. Desert shrub-grassland on shallow and medium depth soils, 30 inches or less in depth, of varying textures and underlain mainly by limestone and gypsum.

III. Desert shrub-grassland on deep soils, 30 inches or more in depth, of varying textures and comprised mainly of alluvium.

IV. Woodland-grassland on all soils of varying depths and textures.

V. Short grassland on shallow and medium depth soils, 30 inches or less in depth, of varying textures and frequently including a caliche hardpan.

VI. Short grassland on deep soils, 30 inches or more in depth, of varying textures, including a caliche hardpan.

VII. Conifer on shallow and medium depth soils 30 inches or less in depth, of varying textures and underlain by igneous rocks, limestone or sandstone.

Plant-Soil Group VII was omitted from the present analysis of infiltration rates because it was inadequately sampled. It occupies only 5 percent of the watershed. Plant-soil groups are delineated on map 12.

84. Range condition.--Within a soil group comprised of soils of similar characteristics, plant cover density is only one of several factors influencing infiltration. Other factors observed from infiltration runs were composition of the vegetation, thriftiness or vigor of the desirable plants, and present activity of erosion. Using these four factors, a guide table was developed to determine the range condition for each of the six plant-soil groups. The guide tables provided for the classification of each plant-soil group into four classes of conditions: excellent, good, fair, and poor. For example, there follows the guide tables used for plant-soil group III and V (table 5). The comparative composition of the good,

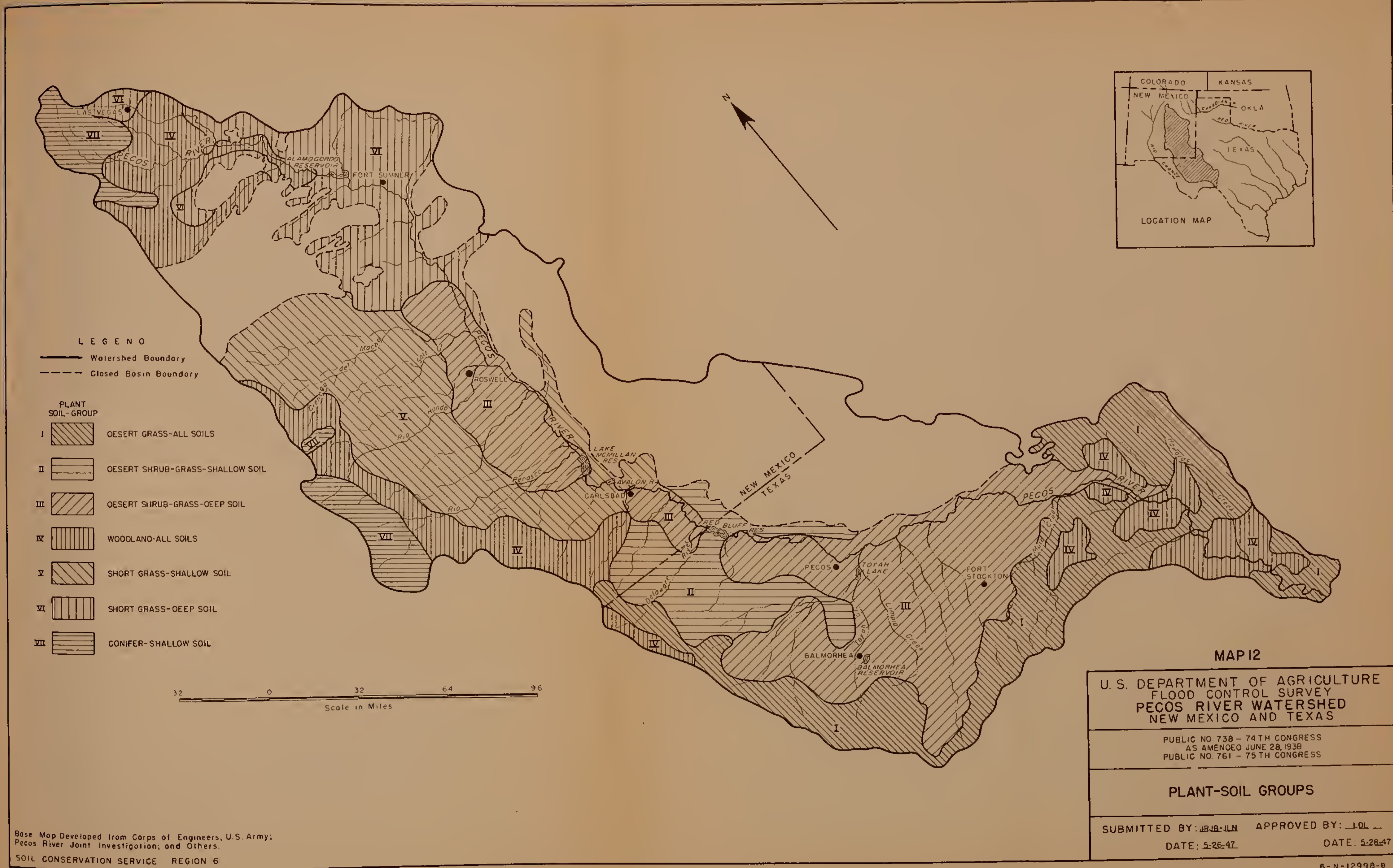
MAP 12
U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS
PUBLIC NO 738 – 74TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 – 75TH CONGRESS
PLANT-SOIL GROUPS
SUBMITTED BY: JBJB-JLN
APPROVED BY: LDL
DATE: 5-26-47
DATE: 5-28-47
LEGEND
Watershed Boundary
Closed Basin Boundary
PLANT SOIL-GROUP
I DESERT GRASS-ALL SOILS
II DESERT SHRUB-GRASS-SHALLOW SOIL
III DESERT SHRUB-GRASS-DEEP SOIL
IV WOODLAND-ALL SOILS
V SHORT GRASS-SHALLOW SOIL
VI SHORT GRASS-DEEP SOIL
VII CONIFER-SHALLOW SOIL
32 0 32 64 96
Scale in Miles
LOCATION MAP
COLORADO
KANSAS
NEW MEXICO
OKLA
TEXAS
N
LAS VEGAS
PECOS
RIVER
ALAMOGORDO RESERVOIR
FORT SUMNER
ROSWELL
PECOS
RIVER
LAKE MCMILLAN RES
AVALON R
CARLSBAD
RED BLUFF RES
NEW MEXICO
TEXAS
PECOS
TOYAH LAKE
FORT STOCKTON
BALMORHEA
BALMORHEA RESERVOIR
PECOS
RIVER
Hondo
Rio
Bose Map Developed from Corps of Engineers, U.S. Army; Pecos River Joint Investigation; and Others.
SOIL CONSERVATION SERVICE REGION 6
6-N-12998-B

Table 5 - RANGE CONDITION CLASSIFICATION GUIDE

Pecos River Watershed

Plant-Soil Group III

FACTORS	CLASSES			
	Excellent	Good	Fair	Poor
I. Composition				
a. Good Plants	70% or more	40-65%	15-35%	0-10%
b. Fair Plants	10-30%	35-50%	55-70%	0-100%
c. Poor Plants	0-10%	0-20%	0-30%	0-100%
II. Plant Cover Density	40% or more	30-40%	20-30%	20% or less
III. Vigor of Good Plants	Maximum	High	Medium	Low
IV. Active Erosion	None	Slight	Moderate	Severe

Plant-Soil Group V

FACTORS	CLASSES			
	Excellent	Good	Fair	Poor
I. Composition				
a. Good Plants	85% or more	65-80%	40-60%	0-35%
b. Fair Plants	0-10%	10-20%	25-40%	0-100%
c. Poor Plants	0-5%	0-15%	0-35%	0-100%
II. Plant Cover Density	45% or more	35-45%	20-35%	20% or less
III. Vigor of Good Plants	Maximum	High	Medium	Low
IV. Active Erosion	None	Slight	Moderate	Severe

fair and poor plants generally determined the condition class except when altered by the density, vigor, or active erosion. Where these factors were one or more grades below that required for a particular class, as determined by composition, the area was placed in the next lower class. For example, if the area classified as "good" according to composition but with the vigor "medium" instead of "high," the area was then classified as "fair." The present condition of the six plant-soil groups was determined through field inspection, and estimates were made as to the changes in condition which are expected to take place with a program. Graphs were prepared for each plant-soil group illustrating the relationship between plant cover density and the infiltration rate at the end of the wet run (f_c). Using the density factor from the range condition classification guide tables for each plant-soil group, the four classes of condition were superimposed on these graphs. (See figures 9 and 10 as examples.) After an area was classified into one of the four conditions according to the guide tables, a determination of the infiltration rate (f_c) could be made by reading directly from the graph of each plant-soil group. In this manner it was possible to use the four factors which influenced the infiltration rate (f_c) based on condition changes expected with a program. A summary of the expected changes in condition and infiltration (f_c) within the six major plant-soil groups is shown in table 6. Complete infiltration curves were then developed for each value of f_c.

85. Precipitation excess.--Having developed infiltration curves for each condition class in each plant-soil group, typical histograms of rainfall for storms of various frequencies were developed (par. 79.) The infiltration curves were then inserted into the typical histograms of rainfall, and the precipitation excess developed for rains of various frequencies. Figures 6 and 7 give an example of precipitation excess for a typical storm. In the analysis of probable rates of run-off for various frequencies under present conditions and in the future with a program, the amount of precipitation excess under these varying conditions from a given storm on a particular watershed is the predominating factor. Customarily this precipitation excess is translated into volume of run-off that might be expected to occur under the above two conditions, and this is translated into peak discharge through peak-volume relationships. Seldom, however, does an entire watershed fall entirely within one plant-soil group. It was, therefore, necessary in the consideration of the probable flood from a particular subwatershed to weigh the precipitation excess in accordance with the area occupied. This was done for each subwatershed studied (Refer to par. 101.)

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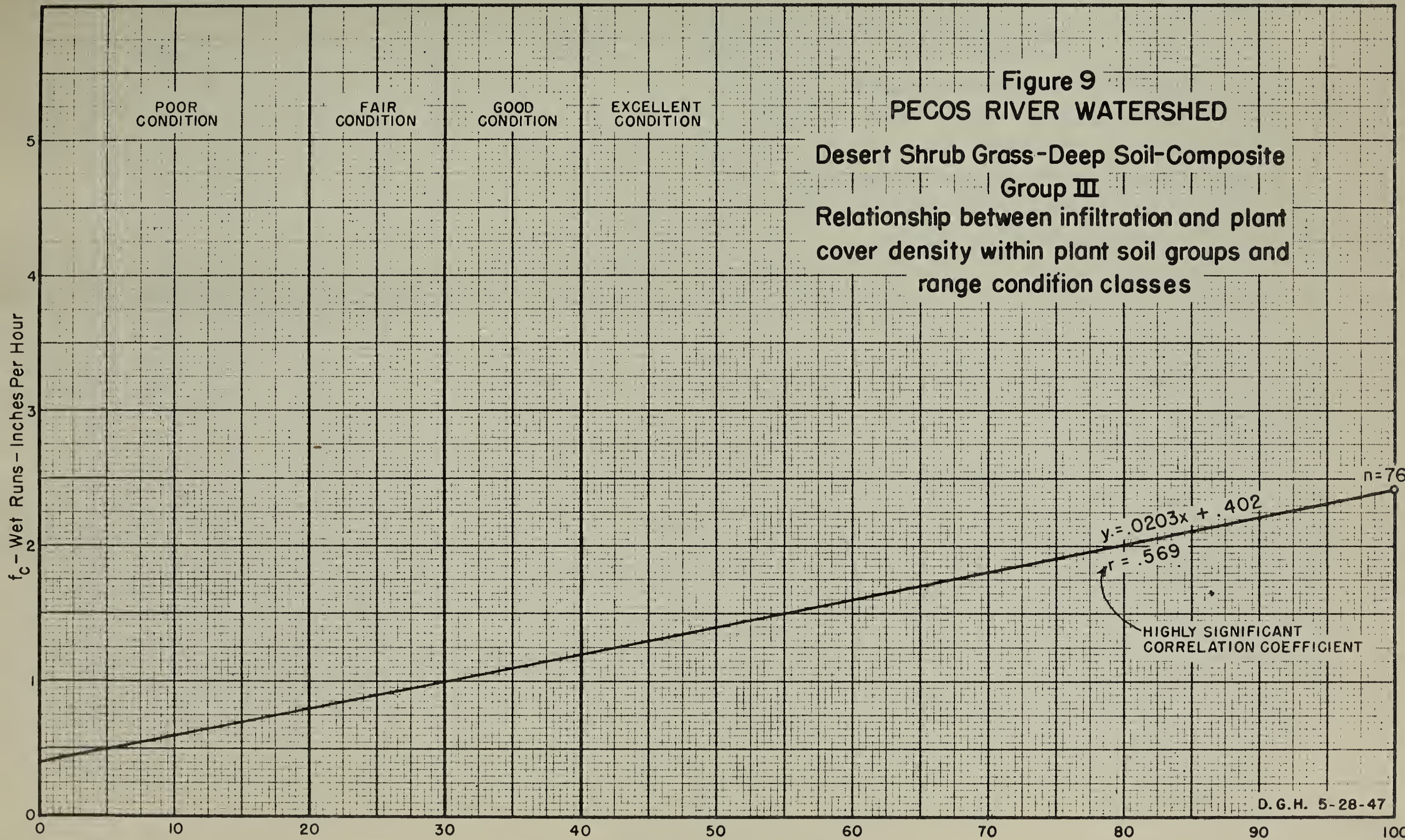
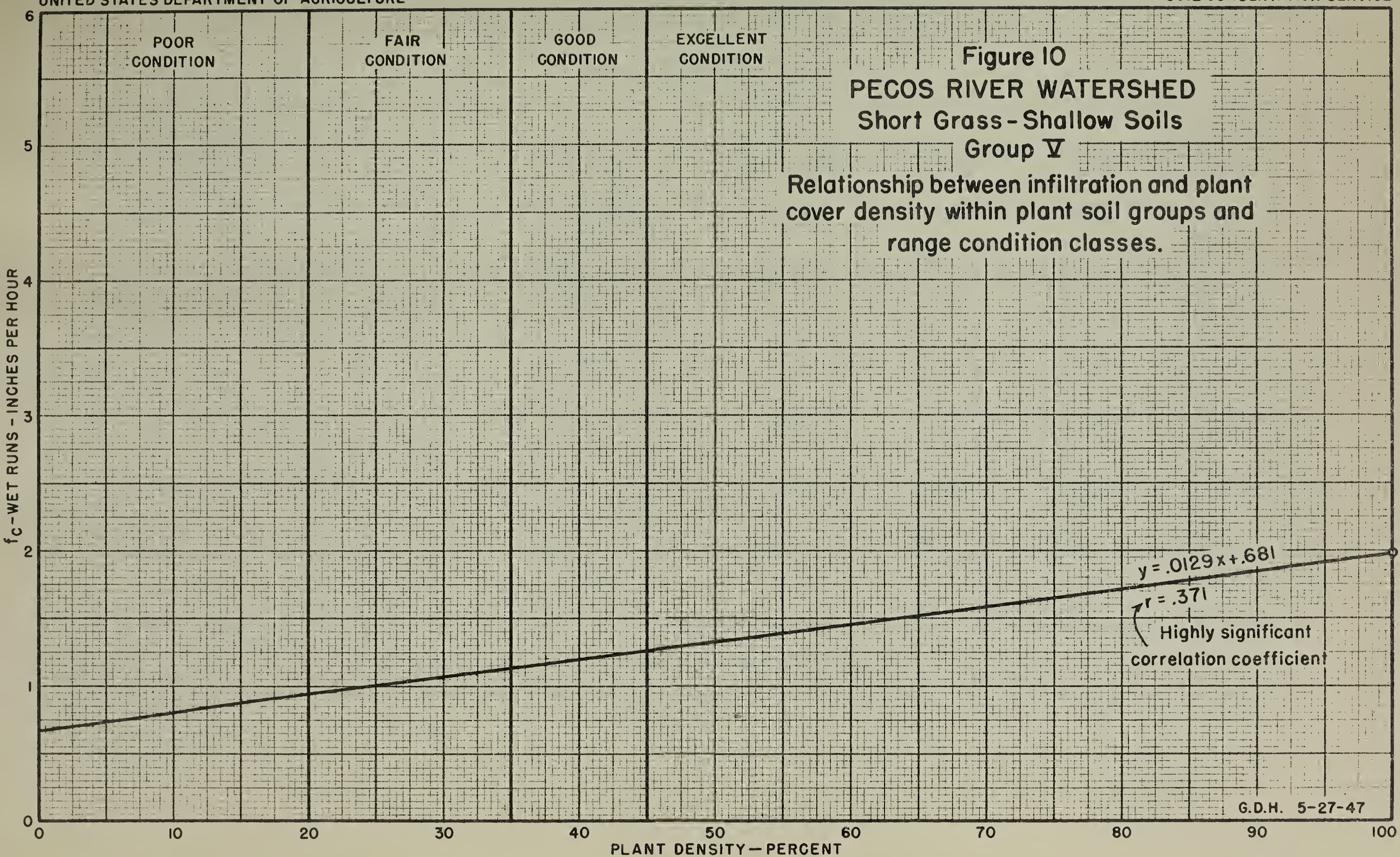


SOUTHWEST REGION

6-L-13078-9 (15)

S.C.S. R6 AUG. 1948 M-75-33

UNITED STATES DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE



SOUTHWEST REGION 6-L-13078-10 (15)

S.C.S. R6 AUG. 1948 M-75-34

Table 6 - SUMMARY OF CONDITION AND EXPECTED INFILTRATION RATES (f_c) BY PLANT-SOIL GROUPS UNDER PRESENT CONDITIONS AND WITH A PROGRAM

Pecos River Watershed

Plant-Soil Group	Acreage	Effect of Program	Condition Classes			
			Excellent	Good	Fair	Poor
I	3,695,800	In./hr. (f_c)	1.25	0.92	0.80	0.67
		Present - %	5	20	40	35
		With - %	20	50	20	10
II	1,489,500	In./hr. (f_c)	1.25	1.10	1.00	0.77
		Present - %	0	0	35	65
		With - %	0	30	40	30
III	5,352,900	In./hr. (f_c)	1.80	1.10	0.90	0.60
		Present - %	0	15	30	55
		With - %	5	35	40	20
IV	3,571,100	In./hr. (f_c)	2.90	1.87	1.45	0.85
		Present - %	0	15	35	50
		With - %	10	40	30	20
V	3,371,700	In./hr. (f_c)	1.50	1.20	1.00	0.76
		Present - %	0	20	45	35
		With - %	10	60	20	10
VI	2,187,100	In./hr. (f_c)	2.50	2.05	1.60	0.85
		Present - %	0	30	40	30
		With - %	10	50	30	10
VII	1,065,700	No Infiltration Analysis Made.				
Total	20,733,800					

Run-off

86. Annual run-off.--The average annual run-off, as recorded by stream gauging stations (See map 13 for locations), shows a progressive increase in average annual discharge of the main Pecos River from 84,828 acre-feet at Pecos, New Mexico, from a drainage area of 189 square miles, to 292,080 acre-feet at Artesia from a drainage area of 15,300 square miles. Below the Artesia gauge, the average annual run-off decreases to 246,245 acre-feet at Carlsbad from a drainage area of 18,100 square miles. At the Red Bluff gauging station a few miles north of the New Mexico-Texas boundary line, the average annual discharge increases to 260,000 acre-feet from a drainage area of 20,544 square miles due to the contribution of base flow from numerous springs and surface flow contributed by the Delaware Creek drainage. At the Comstock gauge, located at the extreme lower end of the watershed just a few miles above the confluence of the Pecos River and the Rio Grande, the average annual discharge is 396,100 acre-feet from a drainage area of approximately 33,200 square miles. A large portion of this discharge is from base flow contributed by numerous springs in the area below Girvin, Texas. Examples of monthly and annual run-off are given in table 7.

87. Records of run-off from tributary watersheds of the Pecos are very fragmentary or cover only short periods of time. Inasmuch as they often include the years of 1941 and 1942, which were extremely unusual, it is very difficult to establish average quantities during supposedly normal years. Amounts of surface run-off (acre-feet per square mile) vary widely within the watershed, not only in proportion to the size of the contributing watershed but also in relation to the amounts and types of precipitation. For example, the average annual run-off on the Pecos River at Pecos, New Mexico, from a forested watershed where there is much snow storage, is 449 acre-feet per square mile. This can be contrasted with the inflow between Guadalupe and Acme, which comes from a low-lying portion of the watershed. The average annual run-off from this area (6,990 square miles) is estimated at only 3.3 acre-feet per square mile. Between these two extremes are watersheds which receive less precipitation than the extreme upper Pecos but still produce much more run-off than the semiarid areas. As an example, the Rio Ruidoso, a watershed of 307 square miles, produces an average of 41 acre-feet per square mile annually. 1/

1/ The years 1941 and 1942 were excluded in arriving at the above comparative yields because of the extremely unusual rains and run-off.

STREAM GAGING STATIONS
1 Pecos River at Pecos, N.M.
2 Pecos River at Anton Chico, N.M.
3 Pecos River at Santa Rosa, N.M.
4 Pecos River at Puerto De Luna, N.M.
5 Pecos River at Guadalupe, N.M.
6 Pecos River at Acme, N.M.
7 Pecos River at Lake Arthur, N.M.
8 Pecos River at Artesia, N.M.
9 Pecos River at Dayton, N.M.
10 Pecos River at Carlsbad, N.M.
11 Pecos River at Malaga, N.M.
12 Pecos River at Red Bluff, N.M.
13 Pecos River at Angeles, Tex.
14 Pecos River at Orla, Tex.
15 Pecos River at Pecos, Tex.
16 Pecos River at Barstow, Tex.
17 Pecos River at Grand Falls, Tex.
18 Pecos River at Girvin, Tex.
19 Pecos River at Sheffield, Tex.
20 Pecos River near Comstock, Tex.
21 Rio Ruidoso at Hondo, N.M.
22 Rio Hondo at Diamond A, N.M.
23 Rio Feliz near Hagerman, N.M.
24 Rio Peñasco at mouth
25 Delaware River near Red Bluff, N.M.
26 Toyah Creek near Balmorhea, Tex.
27 Limpia Creek near Ft. Davis, Tex.
28 Rio Bonita at Hondo, N.M.
Active
Inactive
Watershed Boundary
Closed Basin Boundary
32 0 32 64
Scale in Miles
N
LAS VEGAS
PECOS RIVER
ALAMOGORDO RESERVOIR
FORT SUMNER
ROSWELL
LAKE MCMILLAN RES.
AVALON R.
CARLSBAD
RED BLUFF RES.
NEW MEXICO
TEXAS
PECOS
TOYAH LAKE
FORT STOCKTON
BALMORHEA
BALMORHEA RESERVOIR
Limpia Creek
COLORADO
KANSAS
NEW MEXICO
OKLA
TEXAS
LOCATION MAP
MAP 13
U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS
PUBLIC NO. 738 – 74TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO 761 – 75TH CONGRESS
STREAM GAGING STATIONS
SUBMITTED BY: C.F.R.
APPROVED BY: L.O.L.
DATE: 11-19-47
DATE: 11-19-47
Base map developed from Corps of Engineers, U.S. Army; Pecos River Joint Investigation; and others.
SOIL CONSERVATION SERVICE REGION 6
6-N-12998-K

Table 7. -- EXAMPLES OF AVERAGE ANNUAL RUN-OFF IN ACRE FEET AND MONTHLY DISTRIBUTION

		Pecos River Watershed			
		Pecos River 1/ Pecos, N. M.	Pecos River 1/ Artesia, N.M.	Pecos River 1/ Comstock, Texas	Rio Felix 1/ Hagerman, N.M.
Period of Record		1905-1944	1905-1944	1900-1944	1933-1944
Drainage Area (Sq. Mi.)		189	15,300	35,242	932
Monthly Distribution of Annual Run-off 1,000 ac. ft.	January	1.7	17.5	27.6	0.9
	% of Annual	2.0	5.8	6.7	4.3
	February	1.7	13.4	22.8	0.8
	% of Annual	2.0	4.5	5.6	3.8
	March	2.9	16.6	22.1	0.5
	% of Annual	3.4	5.5	5.4	2.4
	April	9.0	21.3	27.7	0.6
	% of Annual	10.6	7.1	6.8	2.8
	May	22.7	37.2	39.9	4.7
	% of Annual	26.8	12.4	9.7	22.2
	June	17.1	37.4	43.4	1.2
	% of Annual	20.2	12.4	10.6	5.6
	July	8.7	33.6	28.9	1.0
	% of Annual	10.3	11.2	7.1	4.7
	August	7.4	28.6	33.3	1.6
	% of Annual	8.7	9.5	8.1	7.5
	September	5.2	34.8	51.1	6.2
	% of Annual	6.1	11.6	12.5	29.2
	October	3.6	26.6	50.2	1.5
	% of Annual	4.3	8.9	12.2	7.1
	November	2.6	16.1	34.2	1.2
	% of Annual	3.0	5.4	8.3	5.7
	December	2.2	17.1	28.6	1.0
	% of Annual	2.6	5.7	7.0	4.7
Annual Run-off 1,000 ac. ft.		84.8	300.2	409.8	21.2
Annual Run-off 1000 ac. ft.	Maximum	208.9	1,351.0	1,330.9	67.9
	Year	1941	1941	1941	1941
	Minimum	29.2	93.8	159.3	4.4
	Year	1934	1934	1912	1944

1/ Refer to Map 13 for location of gaging stations.

88. Seasonal distribution.—The normal distribution of precipitation through the year is very favorable for the production of run-off during the growing season, particularly in the upper reaches of the watershed. For example, the discharge past Pecos, New Mexico, during the period April-September amounts to 83 percent of the average annual flow. Lower down the watershed, however, the proportion is not as great (64 percent at Artesia) due to the influence of spring flow and the complex irrigation and storage developments above this point. At Comstock, in the lower reach, the run-off occurring during April-September is 55 percent of the total annual.

History of Major Floods

89. General.—Stream gauging records for the watershed date back to 1904. During the period 1904-1916, four major floods occurred, 1904, 1905, 1914, and 1915. A general description of floods occurring since 1916 follows.

90. Flood of August 1916.—The recorded peak at Carlsbad was 85,700 cfs on August 7, while at Dayton on August 9, the average for the day was 1,600 cfs. The inflow, therefore, was from tributaries below Dayton and above Carlsbad; probably from the Penasco or a tributary in its vicinity. The flood at Angeles gave a gauge height of 21.5 and an undetermined discharge. The peak at Angeles in 1937 was 38,900 cfs. The second flood of the month was on August 24, a peak of 7,200 cfs occurring at Dayton and a mean daily peak of 16,500 cfs at Carlsbad on August 23. At Angeles the average flow was 14,000 cfs on the 24th. The peak at Grand Falls, Texas, was 4,370 cfs on August 29.

91. Flood of September 1919.—A tropical hurricane originating south of Florida moved west and entered Texas near Brownsville on September 14, then veered northwest and moved over the Pecos River watershed to be dissipated against the mountains on the west side of the valley. The basin received an average of 3 inches of rain during the period September 14-17. The high center was 9.76 inches at Meek, New Mexico, which occurred between the morning of September 15 and noon of September 17. Buchanan, west of Fort Sumner, recorded over 4 inches on the 16th and Arabela more than 7 inches on the 17th. Carson Seeps, New Mexico had over 8 inches in two days. The run-off from the general rainfall on the western portion of the upper and middle basin resulted in flood flows from Dayton to the mouth of the Pecos. The peak discharge at Guadalupe on the 17th was 5,600 cfs, and a mean daily flow of 40,000 cfs at Dayton on the 18th. Inflow was probably from large tributaries such as the Cienega del Macho. The flood at Carlsbad was reduced to 23,600

cfs (mean daily). Angeles recorded 22,400 cfs on the 20th and at Grand Falls, Texas, the flood was 13,000 cfs on the 25th. The peak flow at Comstock, Texas, was 87,000 cfs on the 16th.

92. Flood of March 1919.--Rainfall during the period March 20-24 was concentrated in the middle and lower basins of the Pecos watershed. Roswell recorded slightly over 5 inches of rainfall for the period, while Grand Falls, Texas, received about 2 inches. Discharges in excess of flood stage were recorded from Dayton to near Grand Falls. The following tabulation shows maximum discharges and dates of occurrence.

Stream	Station	Date	Mean Daily Flow in CFS
Pecos River	Guadalupe	3/24	1,070
" "	Dayton	3/24	26,000
" "	Carlsbad	3/25	23,600
" "	Angeles	3/25	21,000
" "	Barstow	3/26	4,560
" "	Grand Falls	3/29	10,500

Records of peak flows are not available.

93. Flood of August-October 1932.--Rainfall for the period August 27-31 in eastern New Mexico and western Texas had two main centers, Roswell and the Fort Davis-Balmorhea area. Roswell recorded 3.87 inches between August 27 and 29. Fort Davis received 3.90 inches on August 27 and 5.30 inches on August 29. Balmorhea recorded 2.72 inches on August 30. The main center of the storm was over the Devils River Basin in southwestern Texas, where 13.74 inches fell at substation 14 during two days, August 31 and September 1. Rainfall during the second storm period was concentrated in the Alpine-Balmorhea area. On September 6 and 7, Alpine received 3 inches of rain and Balmorhea 2.22 inches. During the third storm period, September 22-30, moderate to heavy rains fell almost continuously in the Pecos watershed in the lower New Mexico and Texas portions. From August 29 to September 3, floods occurred on Toyah Creek watershed, having a peak discharge of 14,200 cfs. The peak flow for Limpia Creek near Fort Davis was 13,500 cfs on August 30. On September 1 the peak flow at Comstock, Texas, was 116,000 cfs with a maximum mean daily flow of 57,900 cfs. No flood flow occurred during this period at Angeles, and there are no records of stages on the Pecos River between Angeles and Comstock. On September 7, a peak discharge of 26,100 cfs occurred on Toyah Creek near Balmorhea. The maximum mean daily at Comstock, Texas, was 8,310 cfs on this date. No flood discharge was observed at Angeles during this period, and there are no records of stages on the Pecos River between Algeles and Comstock. Flood flows began simultaneously at all gauges along the Pecos River

between Dayton and Angeles on September 25 and reached almost simultaneous peak stages at these gauges between September 27 and October 1. No flood occurred at the Guadalupe gauge during this period. On October 1, the peak discharge at Angeles was 15,900 cfs. This peak was reduced to 6,360 cfs at Comstock on October 16. The mean daily flow at Dayton was 16,000 cfs on September 30 and 14,500 cfs at Carlsbad on October 1.

94. Flood of May-June 1937.—This storm consisted of three periods of showers and thunderstorms, occurring during May 23-24, May 27-29, and June 1-3. Total precipitation over the entire basin was in excess of 3 inches for the storm periods. Principal rainfall distribution was in three centers: Ragland, with 12.04 inches; White Tail, with 8.9 inches; and Fort Stockton, with 4.4 inches. The greatest 24-hour amounts recorded for the first period was 2.03 inches at Tatum on May 24. For the second period, the greatest recorded amount in 24 hours was at Artesia where 3.14 inches fell on the 28th. The largest 24-hour total for the third period was 2.45 inches on June 1 at Irvin's ranch. A momentary peak of 13,900 cfs occurred in the Pecos River at Santa Rosa on May 27. Peak discharges in the tributaries did not synchronize with high flows in the main stream, as indicated by a peak discharge of 26,500 cfs in Rio Felix at Hagerman on May 29; 24,900 cfs in Rio Hondo on June 1; and 37,700 cfs in Berrendo Creek near Roswell on June 1. On June 2 a peak discharge of 55,200 cfs occurred at Santa Rosa, followed by a peak discharge of 24,800 cfs on June 3 in Alamogordo Creek above the Alamogordo Dam. The Alamogordo Dam reduced these peaks to 23,200 cfs on June 3. In the meantime, on May 28, a peak discharge of 53,300 cfs was recorded at Acme from inflow below Alamogordo Dam, principally from the Cienega del Macho, a tributary of Salt Creek. The peak discharge at Artesia was 51,500 on May 30 and slowly diminished as the flood crest passed downstream. The peak was reduced to 5,530 cfs at Orla, Texas, on June 9 principally by Red Bluff Reservoir, which had about 285,000 acre-feet of available storage capacity at the beginning of this flood. Comstock, Texas, recorded a peak discharge of 1,870 cfs on June 26.

95. Flood of May 1941.—Heavy rains during the period May 20-27 were general over the eastern portion of New Mexico with the greatest mass of rainfall in the period May 20-25. At Carlsbad 2.94 inches fell on the 22d and 6.24 inches on the 22d and 23d. Lake McMillan recorded 5 inches on the 22d, and Pearl (nearby) recorded 4.05 inches on the 24th and 7.15 inches on the 24th and 25th. A major flood occurred throughout the Pecos Basin below Puerto de Luna, the heaviest run-off originating principally on the tributaries between Roswell and Red Bluff Reservoir. On the Rio Hondo at Diamond A Ranch, a peak discharge of 20,500 cfs occurred on May 29. On May 23, 28,700 cfs occurred in the Delaware River near Red Bluff, while in the Rio Felix near Hagerman

9,630 cfs occurred on this date. In this area, North Seven Rivers, Rocky Arroyo above Carlsbad, and Dark Canyon at Carlsbad also experienced floods. These tributary floods did not synchronize, and natural channel storage of the Pecos River flattened out the sharp local peaks. The flood hydrograph on the Pecos River shows a series of peaks each related to flood flows in individual tributaries. Alamogordo Reservoir, with only 14,000 acre-feet available storage at the beginning of the flood, had very little effect in reducing the peak. Red Bluff Reservoir had about 130,000 acre-feet of storage at the beginning of the flood. This storage reduced the flood volume below Red Bluff Dam and delayed and reduced the peak at Orla. Maximum peak flows on the Pecos River were as follows: 26,300 cfs at Puerto de Luna on May 23; 19,100 cfs at Acme on the 24th; 60,000 cfs at Carlsbad on the 22d; 57,700 cfs at Malaga on the 22d, and 52,600 cfs at Red Bluff on the 24th. The maximum mean daily at Orla was 12,200 second-feet on May 30. The peak flow was not recorded.

96. Flood of September-October 1941.--The rainfall during the period September 20-24 was the greatest recorded in New Mexico since the establishment of precipitation records. The three centers of intense precipitation on the Pecos watershed were Alamogordo Dam with 8.52 inches, Bonito Dam with 9.89 inches, and Dave McCollum ranch near the head of Dark Canyon (unofficial measurement), where 21.25 inches were reported during the 3-day period. The intensities at this location were said to have reached 10 inches in six hours on September 20. At Felix 4.5 inches were recorded on the 20th and 7.2 inches in 48 hours. The greatest 24-hour amount at Alamogordo Dam occurred on the 22d where 7.11 inches were recorded. White Tail recorded 4 inches on the 21st and 6.67 inches in 48 hours. Artesia recorded 3.41 inches on the 22d and 6.65 inches in 48 hours. Ten stations distributed through the middle of the Pecos Basin recorded rains in excess of 3.5 inches and averaging 4.23 inches on September 22d. The greatest amounts on the 23d were 3.85 inches at Carlsbad Caverns and 3.75 inches near St. Vrain. Rainfall tapered off on September 24, 25 and 26, but some rainfall occurred over the western portion of the middle basin during the period September 27-29. The heaviest rainfalls reported for this storm were 4.75 inches at Tularosa on the 28th and 4.78 inches at White Tail on the 29th. Isohyets for the storms of September 20-24 and September 27-30 are delineated on maps 14 and 15.

97. The maximum flood on record was recorded on the Rio Felix at Hagerman, Rio Hondo at Diamond A Ranch, Rio Penasco near Hope, and Dark Canyon at Carlsbad. The peak flow on Dark Canyon was estimated at around 100,000 cfs on September 20. On the 22d the peak flows on the Rio Hondo and Rio Felix were 26,500 cfs and 20,000 cfs respectively. The estimated peak flow on the Rio Penasco at the Hope

MAP 14

U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS

PUBLIC NO. 738 – 74 TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 – 75 TH CONGRESS

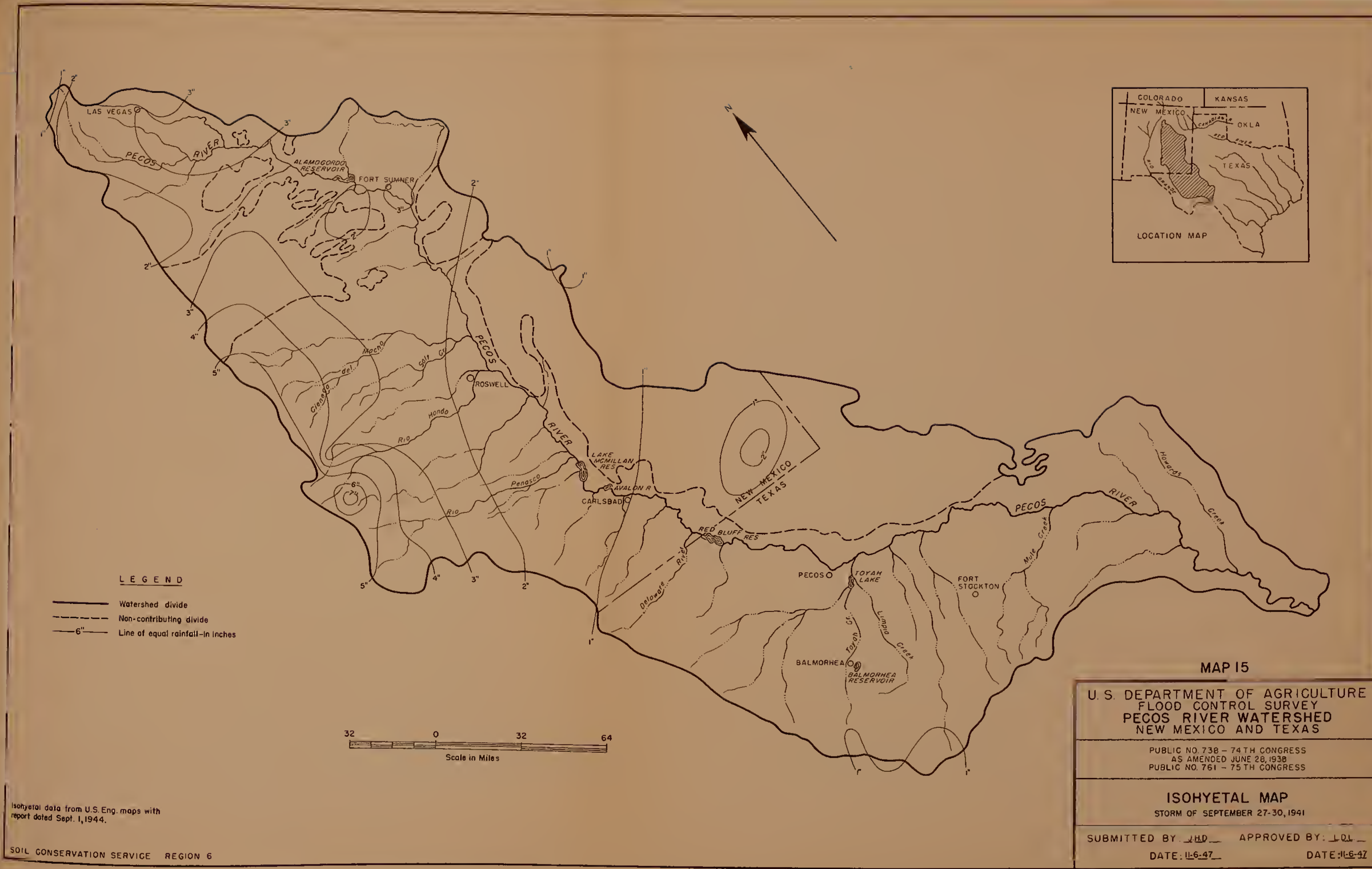
ISOHYETAL MAP
STORM OF SEPTEMBER 20-24, 1941

SUBMITTED BY: J.H.D. APPROVED BY: L.D.L.
DATE: 11-6-47 DATE: 11-6-47

Isohyetal data from U.S. Eng. maps with report dated Sept. 1, 1944

SOIL CONSERVATION SERVICE REGION 6

6-N-12998-H



MAP 15
U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS
PUBLIC NO. 738 – 74TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 – 75TH CONGRESS
ISOHYETAL MAP
STORM OF SEPTEMBER 27-30, 1941
SUBMITTED BY: JHD
APPROVED BY: LDL
DATE: 11-6-47
DATE: 11-6-47
LEGEND
Watershed divide
Non-contributing divide
6" Line of equal rainfall-in inches
Scale in Miles
32 0 32 64
Isohyetal data from U.S. Eng. maps with report dated Sept. 1, 1944.
SOIL CONSERVATION SERVICE REGION 6
LOCATION MAP
COLORADO
KANSAS
NEW MEXICO
OKLA
TEXAS
N
LAS VEGAS
PECOS RIVER
ALAMOGORDO RESERVOIR
FORT SUMNER
ROSWELL
LAKE MCMILLAN RES
AVALON R
CARLSBAD
RED BLUFF RES
NEW MEXICO
TEXAS
PECOS
TOYAH LAKE
FORT STOCKTON
BALMORHEA
BALMORHEA RESERVOIR
Delaware River
Toyah Cr.
Limpia Creek
Mule Creek
Howards Creek
Rio Hondo
Rio Penasco
Salt Cr.
Cienega del Macho

6-N-12998-I

Retard Dam was 75,000 cfs on the 23d. Maximum or near maximum discharges occurred from the Acme gauge to the head of McMillan Reservoir and from the mouth of Dark Canyon near Carlsbad, New Mexico, to Sheffield, Texas. A study of the hydrograph of the Pecos River at Malaga illustrates the influence of tributary inflow on the Pecos River. On September 21, a peak discharge of 63,700 cfs occurred as a result of the Dark Canyon flood of 100,000 cfs. The Black River inflow resulted in a peak discharge of approximately 20,400 cfs on September 22, and on the 26th, as a result of the flood flow from Rio Hondo, Rio Felix, and the upper and central portion of the Pecos watershed, a discharge of approximately 30,200 cfs was recorded. A peak discharge of approximately 19,300 cfs occurred October 3 as a result of a local flood on Rio Hondo and the upper Pecos watershed. The total volume of this September-October flood was the maximum on record along the main stream of the Pecos River with 615,000 acre-feet entering the Red Bluff Reservoir in the period September 19 to October 22 inclusive. All of the reservoirs on the main stream spilled. Considering the total volume of run-off, peak flows on the main stream of the Pecos River were relatively low. Tributary flood flows, as illustrated by the study of the Malaga hydrograph, did not synchronize. The following tabulation shows peak flows at selected stations along the Pecos River as the flood progressed downstream:

Stream	Station	Date	Max. Peak Flow in CFS
Pecos River	Acme	9/23	45,000
" "	Lake Arthur	9/24	49,600
" "	Carlsbad	9/26	33,900
" "	Orla	9/29	23,700
" "	Pecos	9/30	22,200
" "	Grand Falls	10/2	22,000
" "	Girvin	10/5	20,000
" "	Sheffield	10/8	13,800

98. Flood of August-September 1942.--The rainfall during the period August 31-September 1 was general over the entire Pecos Basin with the major portion of the storm centered in the northern part. Unofficial measurements indicated a total precipitation of about 9 inches just west of Alamogordo Dam. The autographic record at Anton Chico indicated 6.68 inches in an 18-hour period from the forenoon of August 31 to the forenoon of September 1. On August 31, 4.4 inches were recorded at Vaughn, at the Las Vegas experimental plot 3.90 inchesoccurred on September 1, and 6.59 inches fell in the 48-hour period from August 31 to September 1. As is to be expected from the rainfall pattern, this flood originated in the upper portion of the basin and was dissipated as it progressed

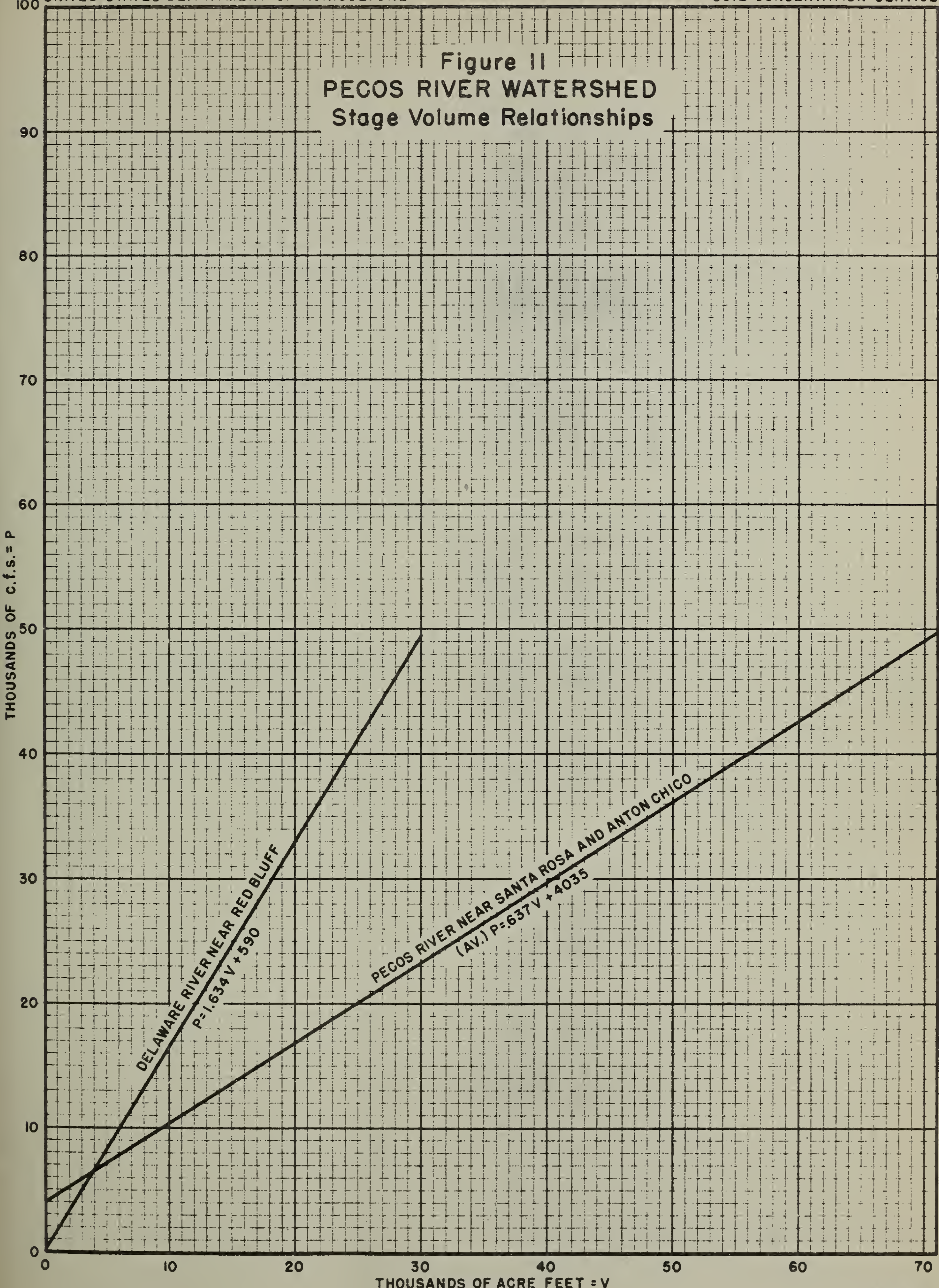
downstream on the Pecos River by channel storage and reservoir regulation. The peak discharge at Anton Chico was 9,850 cfs, 48,600 cfs at Puerto de Luna, and 42,800 cfs at Guadalupe on September 1. Acme recorded a maximum peak of 37,000 cfs on September 2. As the flood progressed downstream, this peak was reduced to 4,890 cfs at Red Bluff on September 8.

Flood Characteristics

99. Stage-volume relationships.--The maximum annual flood flows were tabulated for all gauging stations on the watershed with records long enough to be significant. Peak discharge-volume relationships were worked out for selected stations using the stream gauging records. Figure 11 is an example of these developed relationships.

100. Frequency and magnitude of floods.--Flood frequency relationships for present conditions were worked up for all significant gauging stations where records covered a reasonable length of time. The maximum flood peak flow each year of record was used to determine these probability relationships. Figure 12 illustrates this procedure. At each of these gauging stations the floods that would be equalled or exceeded once in 5, 10, 25, 50, and 100 years were tabulated. The calculated precipitation excess, i.e. surface run-off, for rains of a given frequency was used with the stage-volume relationship curve to check floods of the same frequency, as calculated by the flood probabilities based on actual flood records. Using this method, a reasonable agreement existed in a significant number of cases.

101. Comparison of calculated with actual floods.--Typical watersheds were selected in order to compare the calculated precipitation excess or surface run-off with measured flood flows. A determination was made of the area of the watershed which was occupied by each plant-soil group. Isohyets were drawn for the storm which produced the flood flow and the weighted average precipitation for individual storm was determined. The weighted average precipitation was determined for each plant-soil group in the watershed in calculating the precipitation excess. Total precipitation excess was used as the flood volume. The peak discharge was determined from the stage-volume relationship developed for the watershed from flood flow hydrographs. Where sufficient data were available and the storms were clear-cut, the average variation between calculated peak flow and measured peak was $1\frac{1}{2}$ per cent, and the maximum variation was 24 percent. The following example illustrates the method used:



SOUTHWEST REGION

APRIL 1948
6-L-13078-11(15)

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

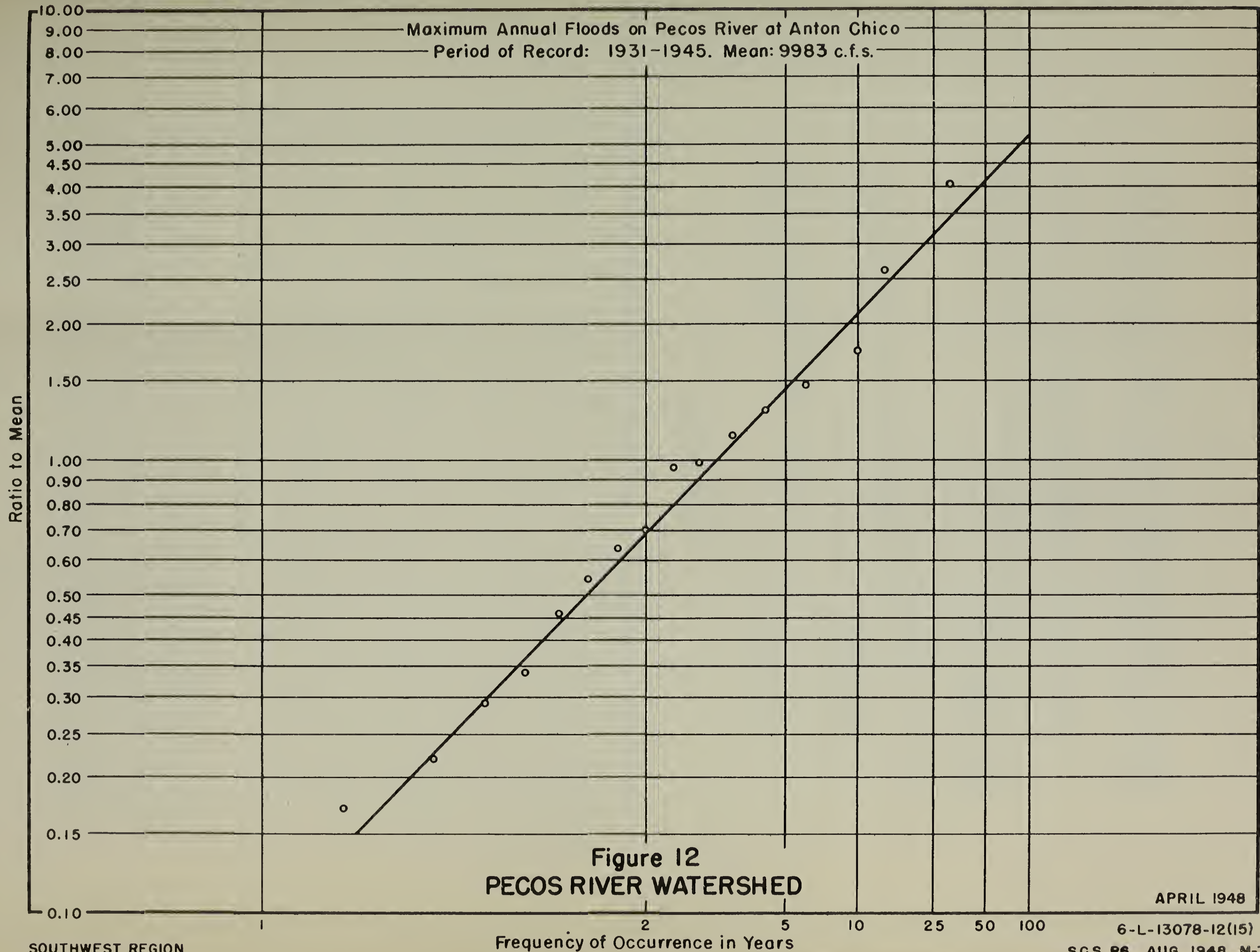


Figure 12
PECOS RIVER WATERSHED

APRIL 1948

6-L-13078-12(15)

SOUTHWEST REGION

S.C.S. R6 AUG. 1948 M-75-36

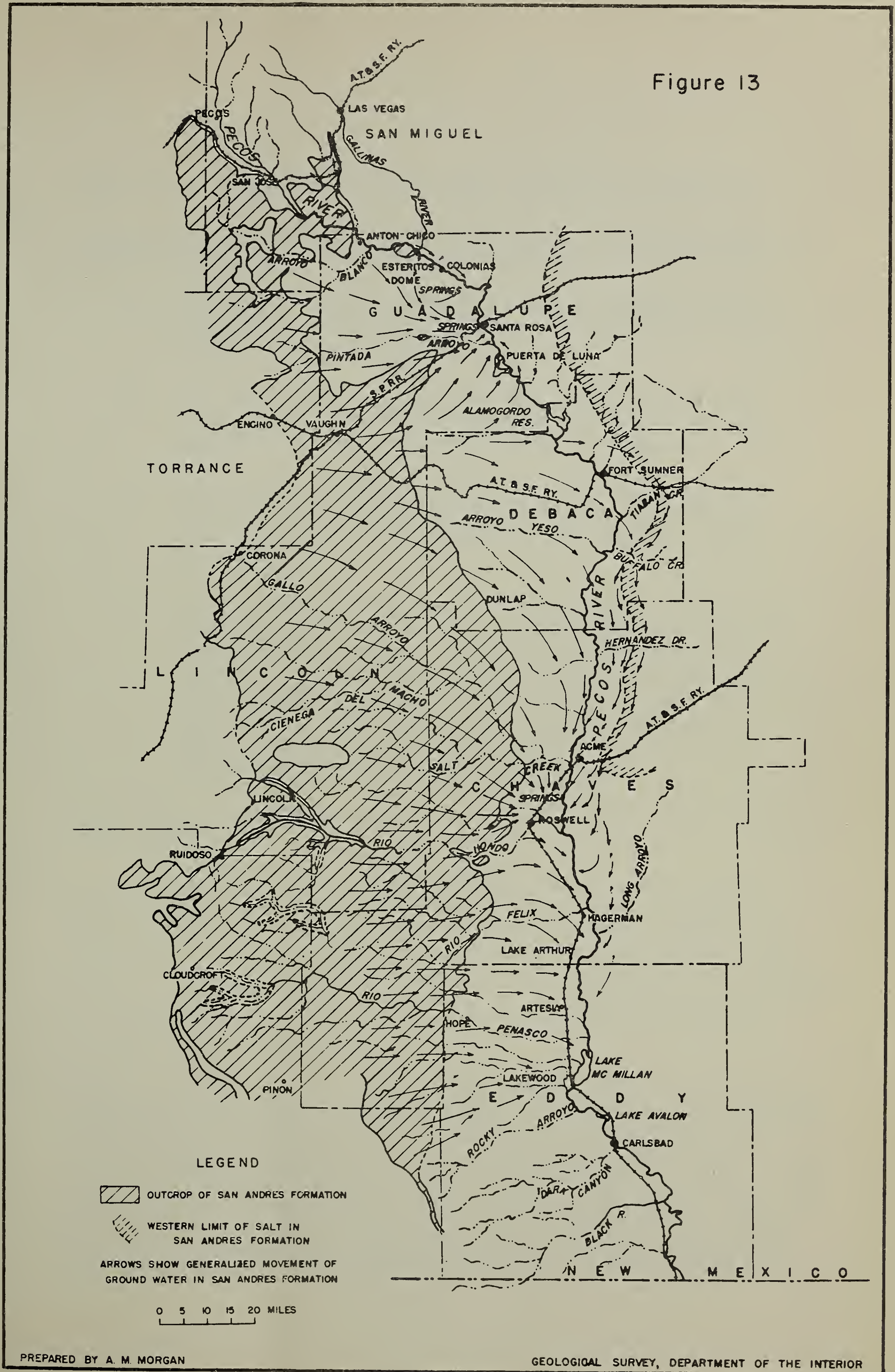
Flood of May 23, 1941, on Rio Felix watershed, weighted average rain was 1.36 inches, covering 450 square miles of the watershed.

Weighted P_e (precipitation excess)	=	0.48 inches
Total calculated volume of surface run-off	=	$\frac{450 \times 640 \times 0.48}{12}$
	=	11,650 acre-feet
Peak discharge from stage-volume relationship	=	9,700 cfs
Actual peak discharge from U. S. Geological Survey Water Supply Paper No. 928	=	9,630 cfs

Ground Water

102. Ground-water movement and storage.--A very small portion of the total precipitation on the watershed percolates to underground storage. Additional increments occur through irrigation losses and seepage from reservoirs. Limestones of Permian and Cretaceous age and alluvium (Quaternary) comprise the important ground-water reservoirs of the area. The Permian, Triassic, and Cretaceous sandstones provide a valuable though relatively small storage capacity. The permian and Cretaceous shales are impermeable and important only as they restrict the movement of ground water. Solution by ground water of the halite, anhydrite, and limestone members of the Permian **series** has led to development of extensive underground channels in these beds. Similar conditions during a former period of exposure probably account for the cavernous condition found at depth in the San Andres limestones of the Roswell Basin. The present drainage pattern has been influenced to a considerable extent by continuing solution and removal of materials. Large portions of the watershed have little or no surface run-off as indicated by the closed basins outlined on Map 1. These areas have subterranean drainage.

103. Throughout much of the Pecos area the formations dip toward the east or southeast. Surface water enters the formations in their respective outcrop areas and filters through each in proportion to the permeability of the individual bed. Water in the rocks then seeps down dip to the main body of ground water. Figure 13 shows the outcrop area of the San Andres formation, principal aquifer underlying the New Mexico portion of the basin, and the



6-L-13078-13(15)

SCS R6 AUG 1948 M-75-37

generalized movement of ground water within the formation.

104. The following criteria indicate that there is little ground-water movement from the Roswell Artesian Basin to adjacent areas.

a. Salt water in the lower San Andres limestone underlying the Roswell Basin denotes little circulation of ground water at depth.

b. The salt water found in the San Andres in deep oil tests east of the river suggests that movement of ground water down dip, away from the basin, is slow.

c. The general absence of solution depressions beyond eight to ten miles east of the river further indicates there is little ground-water movement toward the east.

d. At the Carlsbad Springs, in the southern part of the area, local fracturing and a change in the character of the aquifer combine to bring ground water to the surface. In this locality the bedded Carlsbad limestone grades into the massive and less permeable Capitan Reef limestone. The change of facies minimizes ground-water movement southward into the formations of Delaware Mountain group.

The middle valley is thus shown to be a partially closed ground-water basin.

105. The artesian areas within the watershed comprise the Roswell Basin (figure 14), the valley west of the river and south of Pecos, Texas, and a limited area in the immediate vicinity of that city. Large springs, considered artesian in origin, occur near Roswell, New Mexico; Balmorhea, Fort Stockton, and Grandfalls, Texas. Gradations from artesian to water table conditions exist in adjacent areas. No artesian water is present beneath the remainder of the watershed.

106. Artesian pressure in the Roswell area results from the confining effect of Chalk Bluff clays and shales on water in the underlying cavernous San Andres limestone. Water is held in the Rustler limestone under artesian head by Triassic red beds beneath a large area west of the river between Pecos and Grandfalls, Texas. The depth to water in the Rustler there varies from 900 to 1,800 feet. Successful development at specific locations has proved problematical due to the infrequent occurrence of joint openings and solution cavities in the Rustler limestone. At Pecos, Texas,

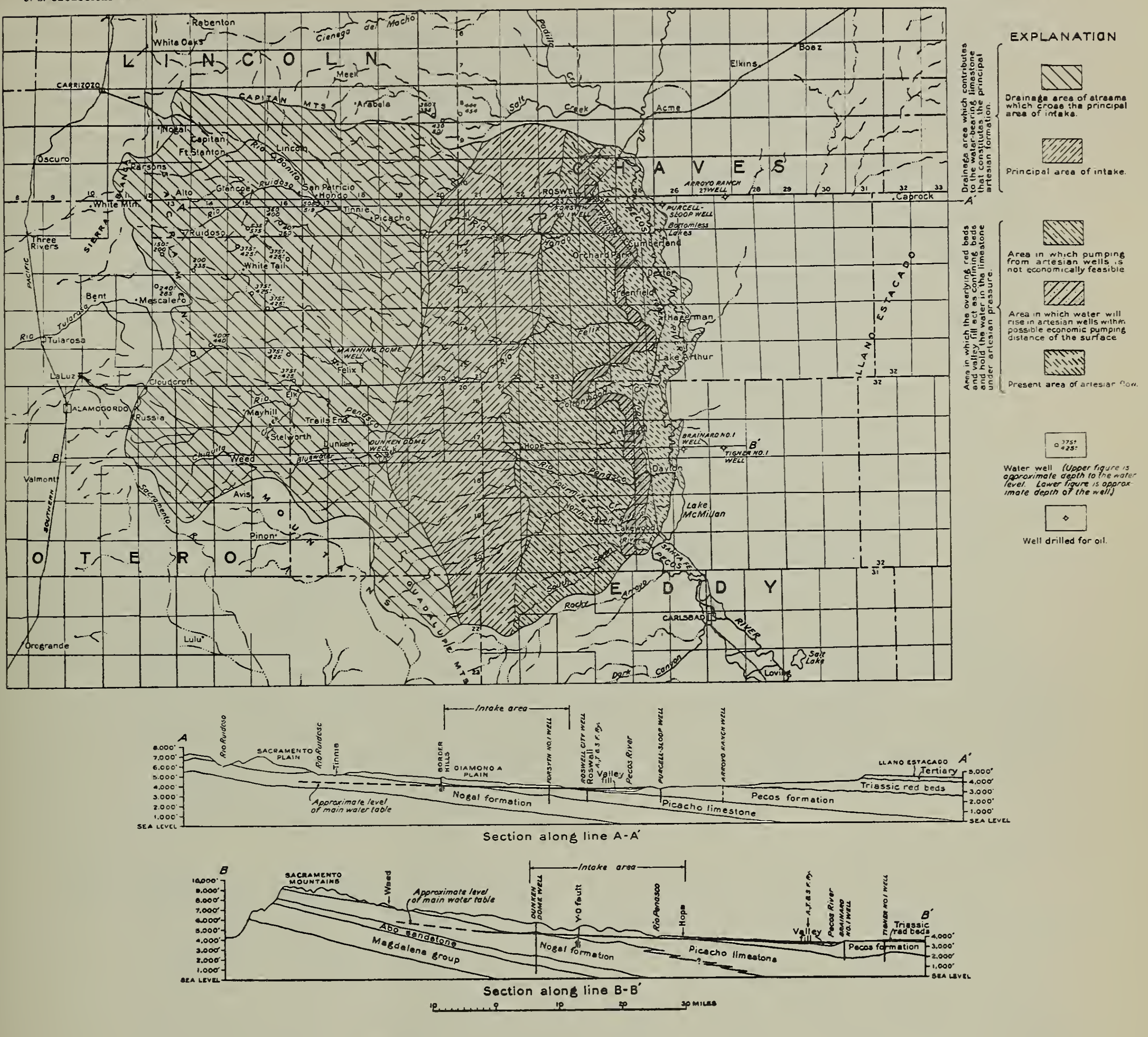


Figure 14

MAP OF SOUTHEASTERN NEW MEXICO SHOWING OUTLINE OF THE ROSWELL ARTESIAN BASIN

The sections across the basin show the relation of the ground water to the stratigraphy and structure

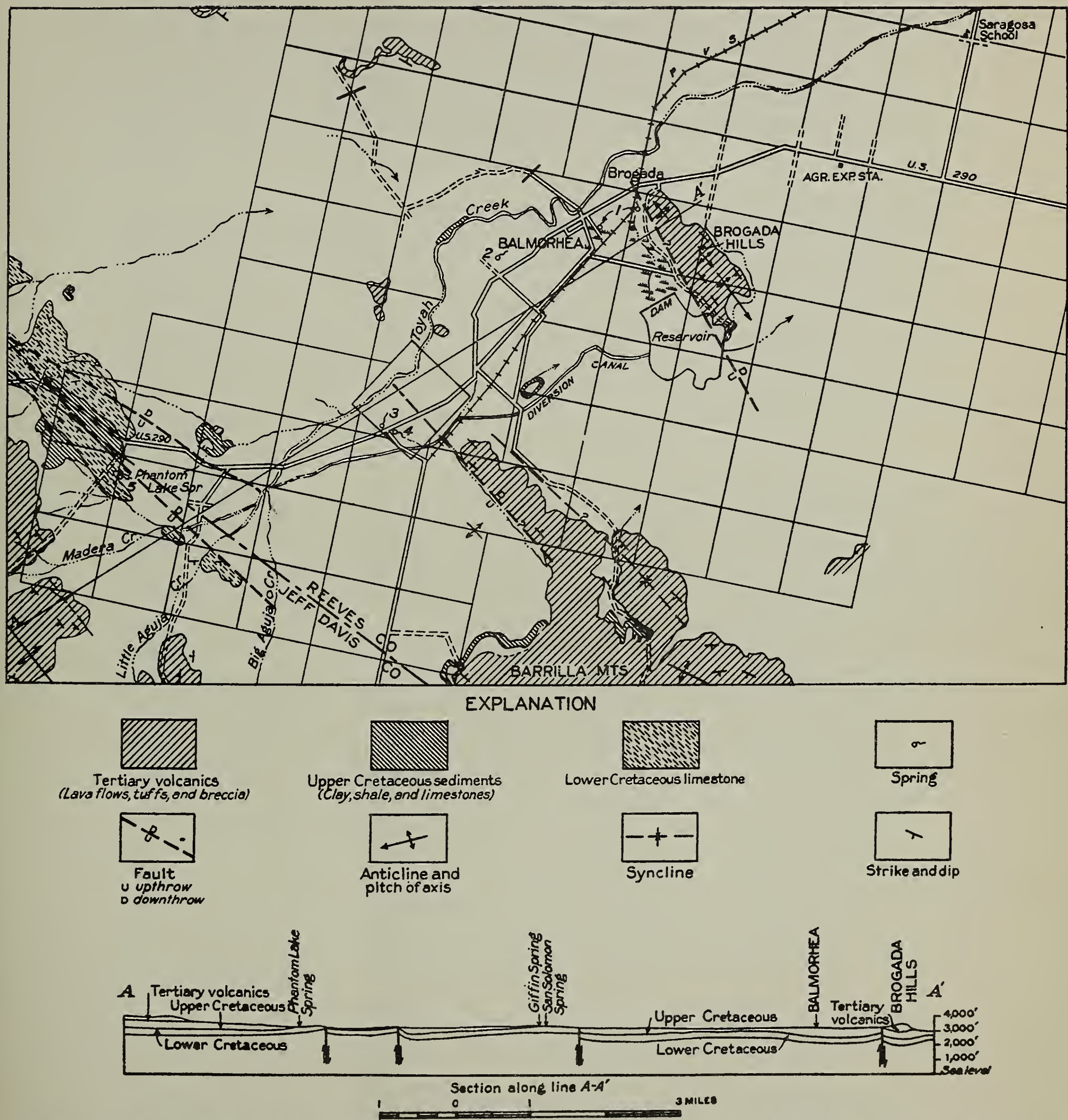
Formation names used in Water Supply Paper 639	Designation by U.S.G.S. used in Report of Participating Agencies, Pecos River Joint Investigation and in this description
Tertiary	Ogallala formation
Triassic red beds	Dockum group
Pecos formation	Chalk Bluff formation or Whitehorse group
Picacho limestone	San Andres formation
Nogal formation	Yeso formation
Abo sandstone	Abo sandstone
Magdalena group	Magdalena formation

S.C.S. R6 AUG. 1948 M-75-38

sufficient static head is present in alluvial aquifers to produce flowing wells from depths of 100 to 200 feet. Here, pressure is developed through a favorable interbedding of permeable lenses upstream and the sealing effect of surrounding fine material.

107. Springs which rise along the river within a short distance south of Santa Rosa, New Mexico, result from underground drainage of areas on the west and the return of subsurface flow to the Pecos channel. The North spring, South spring, and Berrendo spring near Roswell originate as overflow from the artesian reservoir. Their combined flow has declined with the drop of artesian pressure in the basin from an estimated 210 cfs to about 17 cfs at present. The Major Johnson springs located approximately 3½ miles downstream from McMillan Dam have a base flow of some 40 cfs. The source of this water is evidently shallow underground flow of the river. The flow of these springs fluctuates considerably about their base discharge to a maximum of 272 cfs depending upon the volume of water stored in Lake McMillan. The salt springs, which discharge into the Pecos at Malaga Bend, receive approximately 1/2 cfs from the brine aquifer at the base of the Rustler formation. The U.S. Geological Survey has determined that probably 75 to 80 per cent of the mineral matter derived at Malaga Bend comes from this aquifer. The river is fed by seepage from the valley alluvium intermittently throughout the reach between Red Bluff Reservoir and Girvin, Texas. The large springs in the vicinity of Balmorhea, Fort Stockton, and Grandfalls, Texas, are believed due to faulting of Lower Cretaceous and Permian aquifers. Figure 15 shows surface geology and the structural conditions which control the springs west of Balmorhea, Texas.

108. Quality of water.--Most ground water within the Pecos watershed area is somewhat mineralized. The dissolved solids consist of the chlorides, sulphates, and carbonates of sodium, calcium, potassium, and magnesium. The quantities of the various constituents reflect the chemical composition of the formation with which the water has been associated. The degree of salinity varies from a few parts per million to 144,000 ppm (14.4%). The latter concentration is found in the brine aquifers of the Rustler. The Permian formations are the principal source of the salts. The less soluble rocks of Pennsylvanian, Triassic, and Cretaceous time supply relatively small quantities. The Quaternary alluvium has retained a portion of the soluble material contained in the original deposits and is frequently a source of mineralization. Ground water suitable in quality for domestic, livestock, and irrigation purposes is generally available throughout the basin north of the salt springs at Malaga Bend. In the section between Malaga and the Red Bluff Dam, ground water is highly mineralized. It is unfit for human consumption and usable for livestock only in certain localities. Ground-water discharge within this reach is used for



GEOLOGIC MAP AND SECTION OF BALMORHEA AREA, TEXAS, SHOWING THE RELATIONS BETWEEN THE LARGE SPRINGS AND THE GEOLOGIC STRUCTURE.

Figure 15

irrigation after dilution with the surface waters stored in Red Bluff Reservoir. Water obtainable in the lower basin, between Pecos and Girvin, Texas, is generally of much better quality than that in the Malaga-Red Bluff section. It is satisfactory for irrigation and livestock and at most places for domestic use. Ground water in the Edwards Plateau area, impregnated chiefly with $CaCO_3$, is as a rule potable water.

109. Utilization.--Ground-water resources of the Pecos Basin have been intensively developed during the last 50 years. Withdrawals of ground water have exceeded recharge during portions of this period, particularly in the Roswell artesian area. The utilization of shallow water, available in quantity from Quaternary alluvium in the middle valley, increased rapidly during the 1930's. A similar development has taken place in the lower basin, Pecos to Girvin, Texas, since 1940. The water from the springs near Balmorhea, Fort Stockton, and Grandfalls, Texas, is applied to a large acreage through a system of reservoirs and canals.

110. In 1932 the Pecos Valley Artesian Conservancy District was established in New Mexico for the purpose of controlling development and use of ground water in the Roswell area. This agency, by means of conservation measures and strict limitations on the drilling of new wells, has checked the rapid decline in artesian pressure and brought about a more or less stable hydrologic condition in the middle valley. The use of ground water for irrigation in this portion of the watershed has reached maximum economic development. Further expansion must await increased recharge to the underground reservoir. There exists in the lower basin sufficient ground water to support a moderate increase in development for irrigation. The relatively high salt content of the shallow water and the expense and uncertainty involved in obtaining artesian water at depth from the Rustler limestone are adverse factors. The flow from the several large springs in the lower basin is completely utilized. It is not likely that the output of these springs may be increased except through diversion of additional water to the Cretaceous and Permian limestone aquifers. Ground water, in quantity adequate for livestock, is present generally throughout the watershed.

SEDIMENTATION

111. General.—Sediment deposition is an important cause of damage in the Pecos Basin. Not only does it deplete valuable storage capacity of reservoirs at a high rate but also induces flooding by filling channels.

112. Major reservoirs.—Three large reservoirs — Red Bluff, Alamogordo, and McMillan — lie within the basin. Their sedimentation characteristics are discussed below. Map 16 locates these and some of the tributary reservoirs.

Red Bluff Reservoir, located on the southern New Mexico boundary is partly in Texas and partly in New Mexico. It is the largest of the three major reservoirs, having an initial capacity of 310,000 acre-feet at the time of its completion in 1937. A reconnaissance sedimentation survey by the Soil Conservation Service in 1940 showed an annual accumulation of 1,627 acre-feet during the first three years of storage. The annual capacity depletion rate of .52 percent is considered somewhat high because of the abnormal influence of the June 1937 flood and of the survey which was made within 3 years of reservoir completion. Sediment deposited in Red Bluff comes principally from the Delaware, Black Rivers, and Dark Canyon, but an appreciable amount comes from bank erosion along the main stream Pecos River as well as from the upper watershed through lakes Avalon and McMillan.

Alamogordo Reservoir, located above Fort Sumner, was created in 1937 to serve the Carlsbad Irrigation District. Its position in the upper Pecos Basin just below the break in slope of the highest channel gradients is conducive to high sediment rates. Bank cutting, sheet erosion, and gullying are very active in the contributing drainage area. Two sedimentation surveys have been made of the reservoir deposits; the first by the Soil Conservation Service in 1940 when the reservoir was 3.2 years old; and the second by the Corps of Engineers in 1944. The age at time of the 1944 survey was 6.8 years. The measured annual accumulation rate below spillway crest was about 3,600 acre-feet. Stream flow, during the initial period of reservoir use and sediment accumulation (May 27, 1937 to April 1, 1944, was considerably in excess of average runoff as measured at or near the reservoir site from January 1, 1905 to December 31, 1948. Adjusted to the stream flow of the longer period, the annual sediment accumulation rate is about 2,300 acre-feet. On

MAP 16
U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS
PUBLIC NO 738 — 74 TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 — 75 TH CONGRESS
SEDIMENT PRODUCTION
BY AREA AND RATE
SUBMITTED BY: EMT
APPROVED BY: NHB
DATE: 10-25-50
DATE: 10-25-50
LOCATION MAP
COLORADO
KANSAS
NEW MEXICO
OKLA
TEXAS
Alamogordo Reservoir. Original capacity 156,750 acre feet. Built May 1937.
Alamogordo Reservoir Drainage Basin
Closed Basin
Salt Cedar area above McMillan Reservoir. 14,000 acres.
McMillan Reservoir. Original (projected) capacity 90,000 acre feet Built 1894
Avalon Reservoir. Original capacity 7,600 acre feet. Built 1893.
Red Bluff Reservoir. Original capacity 310,000 acre feet. Built 1936.
Macho-Salt Creek Semi-closed Basin
Rio Hondo Semi-closed Basin.
Upper Penasco Semi-closed Basin
Toyah Semi-closed Basin.
Balmorhea Reservoir Original capacity 6,155 acre feet. Built 1916
LAS VEGAS
PECOS RIVER
ALAMOGORDO RESERVOIR
FORT SUMNER
ROSWELL
LAKE McMILLAN RES
AVALON R
CARLSBAD
NEW MEXICO
TEXAS
PECOS
TOYAH LAKE
FORT STOCKTON
BALMORHEA
BALMORHEA RESERVOIR
PECOS RIVER
LEGEND
Sub-basin Boundary
Watershed Boundary
Closed Basin Boundary
SEDIMENT PRODUCTION
Designation | Symbol | Approximate Annual Rate
High | .74 - 3.66 Acre feet per square mile per year
Moderate | .47 - .73 "
Low | .02 - .46 "
Areas labelled "Closed Basin" contribute no sediment to Pecos River Drainage System.
32 0 32 64
Scale in Miles
Base Map Developed from Corps of Engineers, U.S. Army; Pecos River Joint Investigation; and Others.
SOIL CONSERVATION SERVICE REGION 6
6-N-12998-E

the basis of this rate, the capacity depletion on January 1, 1949, was approximately 17 percent.

McMillan Reservoir, located near Carlsbad, New Mexico, is the oldest of the major reservoirs. It was constructed as a relatively small reservoir in 1894. Its later history includes breaching of the dam in 1906, complete drawdowns, and several changes in spillway elevation (1, 2, 5). The original capacity of 32,500 acre-feet would have been 90,000 acre-feet if the present dam and spillways were in existence then. Despite the various changes in characteristics of McMillan Reservoir a rather detailed history of sedimentation is available from several surveys. These indicate a high rate of deposition from completion date to 1915 and a steadily declining rate thereafter. Reason for the decline which started about 1915 is the growth of salt cedar which spread rapidly within and above the reservoir. This soon created a dense growth which acted as a vegetative screen to trap much of the sediment which formerly went into the reservoir basin. Depletion of the projected capacity of 90,000 acre-feet was estimated at 50 percent by 1915 and 67 percent by 1947.

113. Direct drainage.--The river section from the northern divide to Alamogordo Reservoir has been described already as being severely eroded. This is also true of larger tributary streams entering this section, especially Alamogordo Creek, Pintada Canyon, Gallinas River, and Tecolote Creek. These tributaries also receive sediment from thousands of long, deep, actively eroding gullies as well as from extensive areas of sheet erosion. The annual rate per square mile may attain 4 or more acre-feet over large areas.

114. The direct drainage from Alamogordo Reservoir to Lake McMillan includes large areas of grazing land subject mainly to sheet erosion. Much of the sediment thus eroded is deposited before it reaches the Pecos. However, some is derived from main stem bank cutting, some from Taiban, Yeso, and smaller creeks, and still another part escapes through Alamogordo Reservoir. The estimated stream load arriving at the salt cedar area at the head of Lake McMillan is 1,000 acre-feet annually.

115. Direct drainage from McMillan to Red Bluff Reservoirs produces a moderate quantity of sediment because of 1) high trap efficiency of the salt cedar area above Lake McMillan and 2) appreciable areas of bedrock and shallow or no soils on these areas. Principal contributing streams are Delaware and Black Rivers and Dark Canyon.

116. Direct drainage sediment production between Red Bluff Reservoir and the mouth of the Pecos is low in comparison to the large area

involved. Nearly all upstream derived sediment is trapped by Red Bluff Reservoir. Large areas within the reach consist of hard limestones covered by compact, grass protected soils. Many small diversion dams on the main stem serve as effective bed load traps, and they cause diversion of suspended load to irrigated fields. Gravelly terraces bordering the Pecos and larger tributaries contribute some bed load but relatively little of suspended load. Only two or three tributaries entering below Pecos, Texas, are of sufficient size to bring in appreciable amounts of sediment. Sheet erosion and moderate bank cutting are the principal erosion factors. Measured sediment at the mouth of the Pecos shows a minor quantity, but the possibility of a higher contribution during exceptional floods should be considered. Similar areas having like conditions have yielded from .2 to .5 acre-feet per square mile annually. Although the long term annual rate is estimated at 200 acre-feet at the mouth, it is possible that during years of exceptional flows the quantity may reach 1,000 or more acre-feet.

117. Small reservoir storage facilities.—Relatively few minor reservoirs exist in the Pecos drainage basin. Some of the more important smaller reservoirs are Avalon, on the Pecos River near Carlsbad, New Mexico; Lower Parks (Balmorhea), an off-channel reservoir of Madera Canyon near Balmorhea, Texas; Storrie, an off-channel reservoir of the Gallinas River near Las Vegas, New Mexico; and Bonito, on Rio Bonito west of Roswell, New Mexico.

118. Lake Avalon was built in 1893 to serve as a regulator for the Carlsbad Irrigation District. Its small capacity and low trap efficiency cause little effect on main stream sedimentation. Lower Parks Reservoir (Balmorhea) is mainly spring-fed but receives sediment laden flood flows from Madera Canyon through a diversion canal. The annual accumulation of sediment in this reservoir, according to the U. S. Bureau of Reclamation, is 44 acre-feet annually, which would indicate a 22 percent depletion of original capacity between 1916 and 1947 (31 years). Storrie and Bonito Reservoirs lie at high elevation and have low sediment rates. Other small reservoirs near Fort Stockton, Texas, are almost entirely spring-fed, therefore, have little sediment in them. A water retard dam built under the water facilities program in 1941 on the Penasco River near Hope, New Mexico, was almost completely filled by sediment and debris by a single flood. Although its original capacity of 350 acre-feet was small, the filling by one flood indicates a high on-site rate. Several small diversion dams on the Hondo River several years ago have failed, or pool areas were filled by sand in a short period of time.

119. Many stock ponds throughout the Pecos Basin have been filled by sediment in a very few years. No estimate of the total number is available

but random observation of several tanks show that sediment fill is rapid. This is common knowledge to ranchers, and there is at present little tendency to construct earth dams to impound stock water.

120. Partly closed basins.—Several large tributary areas to the Pecos Basin are virtually closed basins most of the time. After long intervals, exceptional rainfall over a wide area produces enough runoff to reach the main river. These basins which are designated "partly closed" contribute little sediment to the main stem, yet large quantities of sediment are eroded and moved within them. One reason for their low contribution is the massing of sediment near the lower end of the tributary drainage. The flows which do reach across this sediment barrier are of fairly short duration and succeed in cutting a relatively narrow trench through it. Some of these constricted basins have serious flood and sediment problems which affect urban and rural population. The largest partly closed basin is Toyah Creek drainage, which includes Toyah and Limpia Creeks, Cherry Canyon, and Salt Draw. The basin terminates in Toyah Lake at the lower end of the drainage. Second in size is Macho-Salt Creek, which consists mostly of grazing land. Next in size is the Hondo River drainage area of 1,716 square miles. This partly closed basin has the most serious flood and sediment problems of those listed because it is well settled and has the largest city, Roswell, near its lower end. The drainage area has several perennial streams tributary to the Hondo River. The Hondo Valley experiences severe gullying, trenching, and sheet erosion. A large area of sediment deposition exists immediately above Roswell and poses a threat of large scale movement of sediment into the city should a great flood occur. An estimated total of 810 acre-feet of sediment is moved annually by water in the Hondo drainage area. The fourth basin classified as partly closed is the upper Penasco. Sediment is accumulating in this area to a marked extent and may soon enter the direct drainage unless corrective measures are taken.

121. Several small structurally closed basins are found within both direct drainage areas and partly closed basins. These do not warrant separate mapping but sediment moving into them is quantitatively important. Damage to grazing land within these basins is a recognized factor and would be affected by an over-all flood control program. Eroded sediment also deposits as colluvium without getting into stream channels. Damage often results. These and other sediment deposits not recognized in other classifications are evaluated and included in the last item of table 8.

122. Channelways and flood plains.—The Pecos flood plain is for the most part narrow, and the channelways are entrenched generally below cultivated areas. Channel filling by sediment is occurring

at the heads of Alamogordo, McMillan, and Avalon Reservoirs. Deposits above crest at Alamogordo amount to more than 600 acre-feet and at McMillan over 22,000 acre-feet as of 1940-41. Much of this is backwater effect, but at McMillan the cause is ascribed chiefly to dense growth of tamarisk or salt cedar. Both the amount of fill and the rank growth of vegetation is caused directly by sediment brought in by the Pecos. Estimate of deposition rate in the salt cedar covered area is 800 acre-feet per year. Many of the large tributaries entering the Pecos north of Artesia have large flat deltas lying between their mouths and the main stem. These represent the accumulation of centuries of geologic erosion. Deposition is so rapid that the channelway to the Pecos is no longer clearly defined. Although these deposits are on land of low agricultural value, they cause damage indirectly by backing up local floods to inundate urban and farm areas. Channel filling below Carlsbad has accentuated flood damage in Dark Canyon by hindering flood flow.

123. Urban and farm areas.—Deposition of sediment has always occurred in connection with local floods. After the Roswell floods of 1937 and 1941, considerable effort and expense was necessary to clean up highways, streets, homes and yards, and city drains. Much of this cannot be evaluated easily, but the amount is believed to be large. Damage by rocks and debris left on cultivated land by overbank floods occurs in the upper part of the Hondo and Penasco River drainage areas as well as elsewhere on other tributaries. This kind of damage is important, and it may be expected to increase as accelerated erosion produces more and heavier debris than the stream systems can transport.

124. In Carlsbad, Pecos, and Balmorhea, flood damage has been largely from water, but there is always some accompanying sediment damage to drains, buildings, and yards.

125. Irrigation ditches and off-channel reservoirs.—Deposition of sediment in irrigation canals and ditches presents a serious problem in irrigated areas not favorably situated below reservoirs which trap most of it. Water diverted directly from upper streams carries considerable sediment, much of which is deposited in irrigation systems. There is a high annual cost of removing sediment from such systems. Off-channel storage reservoirs are subjected to sediment fill as is well shown in Balmorhea Reservoir.

126. Sediment sources and rates of production.—Principal sources of sediment are from 1) bank cutting and trenching, 2) gullying erosion, 3) sheet erosion, and 4) wind erosion. Areas showing the most severe erosion and accompanying production, especially of

the first three types mentioned above are 1) watershed above Alamogordo Reservoir, 2) Rio Hondo Basin, 3) Delaware River Basin, and 4) upper Limpia Creek Watershed. Map 16 shows the relative magnitude of sediment production within the Pecos River Watershed. The annual sediment movement on the watershed is about 17,500 acre-feet. Of this total annual production, about 15,900 acre-feet reaches defined channels.

127. Quantities of sediment listed in table 8 are those which enter defined channelways and would be caught by a reservoir of high trap efficiency built at the lowest end. In addition to channel-moved sediment, approximately 19 percent more is moved temporarily down slopes or by wind. This portion, although not reaching reservoirs, may be equally damaging to farm, urban, and ranch lands. It may also be considered potential stream load because new gully headcuts may later tap it and thus permit its being transported to the main stem. Although not evaluated, a considerable quantity of sediment is diverted into irrigation systems and deposited on farm lands.

128. Sediment sources within plant-soil groups are shown on map 17. The distribution of sediment production from sheet and rill erosion by land use and within plant-soil groups is shown in table 9.

129. Anticipated trends of sedimentation under present conditions.— Prediction of future conditions based on present conditions is necessarily subject to considerable error, especially in a semiarid climate. First it is necessary to decide how far erosion has progressed in the Pecos drainage basin with respect to its ultimate condition. The upper Pecos area may have reached its maximum erosion development; the middle Pecos is moderately affected, and the lower part is still in its early stages. Considering all factors, it is believed that rates of sediment production will not increase more than 10 percent without a flood control program. Some of the factors leading to this conclusion are:

a. The present rates as determined are slightly overweighted by inclusion of too many wet seasons in the short available record. This weighting will take care of some increase in rates.

b. Erosion conditions are partially self-limiting after an initial period of increase. Land use on the Pecos is probably near its maximum because all water is appropriated and little or no "new" water is available. The geology and topographic conditions preclude extensive increase of some types of erosion. Numerous rock base levels have been reached

Table 8 - **ESTIMATED SEDIMENT PRODUCTION**

Pecos River Watershed

UNIT	SEDIMENT PRODUCTION INTENSITY 1/			DRAINAGE AREA 2/	SEDIMENT TRANSPORTED		SEDIMENT RATES	
	Low	Moderate	High		To Reservoirs 4/	On-site	Reservoir	On-site
	area pct.	area pct.	area pct.	sq. mi.	ac.ft./yr.	ac.ft./yr.	ac.ft./sq.mi. per year	ac.ft./sq.mi. per year
Direct Drainage:								
Above Alamogordo Reservoir	16	58	26	3,749	2,300	4,500	.62	1.2
Alamogordo to McMillan	43	44	13	5,746	1,000	4,000	.17	.70
McMillan to Red Bluff	43	57	>1	3,728	1,600	3,000	.43	.80
Red Bluff to Mouth	81	19	0	10,815	200	1,000	.02	.09
Subtotal				24,038	5,100	12,500		
Partly Closed Basins:								
Macho-Salt	93	7	0	2,998	100	800	.03	.27
Hondo	48	29	23	1,716	300	810	.17	.47
Upper Penasco	87	0	13	741	100	350	.13	.47
Toyah Creek	55	45	0	3,729	250	1,550	.07	.42
Subtotal				9,184	750	3,510		
Unspecified by Place 3/				-	-	1,521	-	-
Total				33,222	5,850	17,531		
Average	60	34	6				.18	.53

1/ Range in rates, approximately: Low .02-.46; moderate .47-.73; high .74-3.66 ac.ft./sq.mi./yr.

2/ Drainage areas exclusive of large closed basins. From unpublished Survey Report, Pecos River and tributaries, Texas and New Mexico, U. S. Engineer Office, Albuquerque District, September 1, 1944.

3/ Evaluated from soil surveys and field reconnaissance observations. See paragraph 121 for explanation.

4/ Evaluated for existing and potential reservoirs constructed near or at lowest part of drainage area. This is the residual quantity of the gross sediment transported and evaluated as on-site rate.


MAP 17
U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS
PUBLIC NO. 738 - 74 TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 - 75 TH CONGRESS
SEDIMENT SOURCES WITHIN
PLANT-SOIL GROUPS
SUBMITTED BY: J.L.N.
APPROVED BY: L.D.L.
DATE: 6-6-47
DATE: 6-6-47
6-11-12998-A
LEGEND
Watershed Boundary
Closed Basin Boundary
SEDIMENT SOURCES WITHIN
PLANT-SOIL GROUPS
PLANT-SOIL GROUPS
I DESERT GRASS-ALL SOILS
II DESERT SHRUB-GRASS-SHALLOW SOIL
III DESERT SHRUB-GRASS-DEEP SOIL
IV WOODLAND -ALL SOILS
V SHORT GRASS-SHALLOW SOIL
VI SHORT GRASS-DEEP SOIL
VII CONIFER-SHALLOW SOIL
SEDIMENT CONTRIBUTION INDEX
HIGH
MEDIUM
LOW
32 0 32 64 96
Scale in Miles
Base Map Developed from Corps of Engineers, U.S. Army; Pecos River Joint Investigation; and Others.
SOIL CONSERVATION SERVICE REGION 6
LOCATION MAP
COLORADO
KANSAS
NEW MEXICO
OKLA.
TEXAS
N
LAS VEGAS
PECOS RIVER
ALAMOGORDO RESERVOIR
FORT SUMNER
ROSWELL
LAKE MCMILLAN RES
AVALON R.
CARLSBAD
RED BLUFF RES
NEW MEXICO
TEXAS
PECOS
TOYAH LAKE
FORT STOCKTON
BALMORHEA
BALMORHEA RESERVOIR
PECOS RIVER

Table 9 - ESTIMATED SEDIMENT PRODUCTION FROM SHEET AND RILL EROSION BY LAND USE AND PLANT-SOIL GROUPS PRESENT AND WITH A FLOOD CONTROL PROGRAM

Pecos River Watershed

Plant-Soil Group	Area sq.mi.	Condition	PRESENT CONDITIONS Cond. %	Sed. Rate per sq.mi.	Weighted Sediment Yield	Sed. Yield ac.ft.	WITH FLOOD CONTROL PROGRAM Cond. %	Weighted Sediment Yield	Sed. Yield ac.ft.	Percent Reduction	Sediment Reduction ac.ft.
I.											
Desert Grass	5,775	Excellent	5	.00	.00	0	20	.00	0		
All Soils		Good	20	.08	.016	92	50	.04	231		
		Fair	40	.25	.10	578	20	.05	289		
		Poor	35	.35	.12	695	10	.035	202		
Total						1,363			722	47	641
II.											
Desert Shrub-Grass	2,327	Excellent	00	.00	.00	0	00	.00	0		
Shallow Soils		Good	00	.10	.00	0	30	.05	70		
		Fair	35	.30	.105	244	40	.12	279		
		Poor	65	.40	.26	605	30	.12	279		
Total						849			628	26	221
III.											
Desert-Shrub-Grass	8,365	Excellent	00	.00	.00	0	5	.00	0		
Deep Soils		Good	15	.08	.012	100	35	.028	234		
		Fair	30	.25	.075	627	40	.10	836		
		Poor	55	.41	.2275	1,903	20	.07	585		
Total						2,630			1,655	37	975
IV.											
Woodland	5,580	Excellent	00	.00	.00	0	10	.00	0		
All Soils		Good	15	.10	.015	84	40	.04	223		
		Fair	35	.20	.070	391	30	.06	335		
		Poor	50	.50	.25	1,395	20	.10	558		
Total						1,870			1,116	40	754

Continued on following page.

Table 9 - Continued

Plant-Soil Group	Area sq.mi.	Condition	PRESENT CONDITIONS Cond. %	Sed. Rate per sq.mi.	Weighted Sediment Yield	Sed. Yield ac.ft.	WITH FLOOD CONTROL PROGRAM Cond. %	Weighted Sediment Yield	Sed. Yield ac.ft.	Percent Reduction	Sediment Reduction ac.ft.
V.											
Short Grass	5,268	Excellent	00	.00	.00	0	10	.00	0		
Shallow Soils		Good	20	.10	.02	105	60	.06	316		
		Fair	45	.40	.18	948	20	.08	421		
		Poor	35	.60	.21	1,106	10	.06	316		
Total						2,159			1,053	51	1,106
VI.											
Short Grass	3,417	Excellent	00	.00	.00	0	10	.00	0		
Deep Soils		Good	30	.05	.015	51	50	.025	85		
		Fair	40	.10	.04	137	30	.03	103		
		Poor	30	.70	.21	718	10	.07	239		
Total						906			427	53	479
VII.											
Coniferous Forest All Soils	1,665	All Conditions			.10	167		.07	117	30	50
Subtotal (Range and Forest)	32,397					9,469			5,718	40	3,751
VIII.											
Dry-Farm Land All Soils	234				1.80	421		.50	117	72	304
IX.											
Irrigated Land All Soils	430				.80	344		.30	128	63	216
Other Land 1/	139										
TOTAL	33,200 2/					10,234			5,963	42	4,271

1/ Bare rock, lava flows, and other nonvegetated surfaces.
2/ Area exclusive of closed basins.

throughout the stream system. Many large gullies have deepened and broadened until their capacity is adequate to carry flood flows without excessive erosion.

130. Trenching of tributary streams, such as the Hondo and upper Penasco, has not reached its peak, and high sediment rates will not only increase but will be extended to other tributaries not yet affected. The narrow flood plain of the upper Hondo Valley, as now tilled, is highly vulnerable to destruction, which, if accomplished, would displace a large number of persons who depend almost entirely on agriculture. The sediment coming from this source will deposit mainly in the Roswell area. Agriculture in the Tecolote-Gallinas area above Alamogordo is now severely handicapped because of gully and sheet erosion. There is no reason for hoping that the condition will improve without some corrective program. Bank cutting along the Pecos River may be expected to continue at its present rate. In addition to increasing the sediment load, it is destroying agricultural and urban land near Fort Sumner. Sediment derived from bank cutting in the Fort Sumner area exceeds .5 acre-feet per linear mile annually. The lateral cutting ranges from a few inches to several feet during large floods. Clear water releases from Alamogordo Reservoir cause serious bank cutting over relatively long periods of time.

131. The on-site rate of sediment production may be several times the downstream rate because much of the eroded sediment is deposited in the vegetated channel area just below the Fort Sumner irrigated district. Other places, such as on the Arroyo Hondo above Roswell and the Gallinas-Tecolote Rivers, have high on-site rates but a relatively low downstream rate because of deposition on fans or in wide downstream channels. Lack of adequate records or detailed surveys of bank cutting make a precise evaluation impossible. It is felt that the results presented in this report are very conservative and that future determinations will show more sediment rather than less.

132. Channel deposition will continue above the heads of McMillan and Alamogordo Reservoirs, and deposition will begin later at Red Bluff Reservoir. The chief losses are consumption of water by salt cedar growth on the sediment deposits, swamping of adjacent flood plain lands, and creation of mosquito breeding areas with danger of spread of malaria.

FLOOD PROBLEMS AND FLOOD DAMAGES

133. Extent of flood problem.—Damaging floods are of frequent occurrence on the Pecos River from the town of Pecos, New Mexico, to Girvin, Texas, a distance of almost 700 miles. With the construction of international reservoirs on the Rio Grande below the mouth of the Pecos, the flood problems of the Pecos will be extended several hundred miles by its contribution of sediment to the Rio Grande. Tributaries such as the Gallinas River, Rio Hondo, Rio Penasco, Dark Canyon, Toyah Creek, and other lesser ones extend the flood problem to practically the entire watershed. It follows, therefore, that a program in the aid of flood control must encompass the major portion of the watershed.

134. Nature of the problem.—Flood records show that floods generally occur during May and June or September and October. Either period falls within the growing season and as a consequence, crop losses are generally a major item of damages. General storms producing floods over a vast area occurred in 1941. These storms produce high peak discharges not only on the main stream but also on the tributaries. Local storms may produce higher peak flows on tributaries than general storms, but these flows are soon reduced to non-damaging magnitude on the main stream. Since 1932, twelve damaging floods have occurred somewhere on the watershed and in 1941 two serious floods occurred.

135. Types of flood damages.—Some of the more important types of flood damages that have occurred and will probably recur unless vigorous action is taken to prevent them are discussed by reaches and tributaries in subsequent paragraphs.

136. Upper Pecos.—From the headwaters to Alamogordo Reservoir, the major flood damage is the destruction of irrigation systems. These systems are for the most part dependent upon cheaply constructed diversion dams which have a life of from 3 to 5 years. When these dams wash out, land under the system is generally without water for the remainder of the growing season, and in many instances, replacements are not made by the following year. After the 1937 flood, thousands of dollars in loans or outright grants were made available by various public agencies to repair the flood damage. Since 1932, it is estimated that damage to irrigation works with resultant decrease in crop production has amounted to $648,000. This does not include the value of land abandoned because of inability to maintain irrigation structures. Since 1900, 1,500 acres or more than 50 percent of the irrigated land on Tecolote Creek and the

Gallinas River (exclusive of the Storrie project) have been abandoned primarily for this reason. As channels become sediment filled or widen and deepen, as the case may be, there is reason to believe that abandonment of irrigated land will continue. Other important damages include 1) damage to land and irrigation ditches by deposition of sediment both from overflow of the main stream and also from side washes; 2) loss of agricultural land by bank caving (55 acres in last 8 years); 3) damage to crops by inundation; and 4) washing out of bridges and highways.

137. Fort Sumner area.—This area includes the reach of the Pecos from Alamogordo Reservoir to Highway 380 east of Roswell. The Pecos River meanders through the Fort Sumner district, and active bank cutting occurs at several points not only during flood flows but also during periods when irrigation water is released from Alamogordo Reservoir for the Carlsbad irrigation project. In 1937 it was estimated that 100 acres of valuable irrigated land was swept down the Pecos to lodge in and above McMillan Reservoir. In 1941 and again in 1942, the district's diversion dam was seriously damaged and is now being replaced by the Bureau of Reclamation. Another comparable flood may change the course of the Pecos and isolate 800 to 1,000 acres of agricultural land. Crop damage is less important in this reach because floodwaters inundate only a few hundred acres. Railroads and highways have experienced considerable damage at the Pecos crossings near Acme. Bridges were washed out in 1937 and again in 1941. The highway during the latter flood was closed to traffic for 35 days. Traffic surveys indicate that the detouring incident to the bridge washout was at least 750,000 vehicle miles.

138. Roswell-Artesia area.—This area includes the reach of the Pecos from U. S. Highway 380 east of Roswell to the head of Lake McMillan. Flood stages in this reach are increased by tributary inflow from Rio Hondo, Berrendo Creek, Rio Felix, Cottonwood Creek, and Rio Penasco. The concentration of agricultural property within this flood plain makes it particularly susceptible to flood damage. Crop losses account for almost three-fourths of all floodwater damages. Deposition and erosion of farm land necessitating releveling is another important flood damage.

139. Carlsbad area.—This area includes the reach from Lake McMillan to Red Bluff Reservoir. The small amount of property in the flood plain and large channel capacity make this reach relatively unimportant insofar as the flood hazard from the Pecos itself is concerned. A flood great enough to wash out McMillan and Avalon Dams is possible. In that event it has been estimated that Carlsbad would be under from 6 to 10 feet of water and probably many lives would be lost.

140. Red Bluff to Girvin.--This reach includes all of the agricultural area along the Pecos in Texas. Some measure of flood protection is afforded by Red Bluff Reservoir, constructed in 1936. Experience has amply demonstrated, however, that the protection offered is not complete. Almost 5,000 acres of agricultural land was flooded in 1941. The flood destroyed crops and washed land and irrigation borders. Highways were damaged and water entered the outskirts of the city of Pecos. An electric generating plant at Girvin was shut down for several days because of the flood.

141. Salt and Berrendo Creeks and Rio Felix.--These tributaries pass through highly developed agricultural areas before reaching the Pecos. Channel capacities are limited and floodwaters inundate considerable land. Most of the damage done by floods on these tributaries involves agricultural property or highways.

142. Rio Ruidoso, Rio Bonito, Rio Hondo above Hondo Reservoir, and Rio Penasco.--Agricultural areas along these tributaries lie in narrow valleys along the streams. For this reason and because of the steep gradient, small floods do great damage. Large floods can practically ruin an entire valley. Although much rehabilitation work has been done, these valleys still bear the scars of the 1941 flood. Based on present price levels, agricultural damage from the 1941 flood alone averaged almost $100 per acre of irrigated land. Residents have expressed the fear that another flood of the magnitude of 1941 would render these valleys useless for agriculture. This fear is probably not without foundation. Of the approximately 8,000 acres of irrigated land in the Ruidoso, Bonito, upper Hondo, and upper Penasco Valleys, more than 3,000 were flooded in 1941. More than 300 acres caved into the streams. Deposition of boulder and gravel fans on farm land was widespread. Reclaiming these areas at a cost of $50.00 or more per acre is still going on. Practically all of the diversion dams were destroyed or seriously damaged. On the Ruidoso and upper Hondo alone, it was estimated that 600 acres of productive orchards were killed because of interruption of irrigation services. The Hope retard dam on the Rio Penasco, just completed before the 1941 flood at a cost of $60,000, was practically filled by sediment and debris.

143. Dark Canyon and lower Rio Hondo.--Extensive damage is caused at Carlsbad by floods from Dark Canyon. Minor flood damage occurs on Hackberry Draw. Floods are frequent in the Rio Hondo and result in widespread damage in the city of Roswell. The survey report on the Pecos River which is being prepared by the Corps of Engineers will indicate the extent of flood damages at these points and will describe flood control measures needed for flood protection.

144. Toyah Creek and vicinity.--This area is located in the vicinity of Balmorhea, Texas, near the foothills of the Davis Mountains. Flash

floods, generally of short duration, overflow stream channels and cause damage principally to farm property and highways. After passing through the agricultural area, Toyah Creek flood flows spread over range land and flow into Toyah Lake, a natural lake southeast of Pecos, Texas. Only rarely does this lake overflow and no damage results unless the Pecos is in flood stage. The area considered does not include Salt Draw, Cottonwood Creek and their tributaries. A preliminary flood damage survey of this area in the vicinity of Pecos, Texas has been made by the Corps of Engineers.

145. Unallocated damages.--The Forest Service incurred considerable flood damage in national forests in 1941. Roads and trails, camp ground and recreational areas, and range improvements were heavily damaged. Although these damages were appraised only for the 1941 flood, other floods have caused some damage. Damage to range improvements and livestock losses have occurred elsewhere. Because of their scattered nature, these damages have not been appraised but they are important.

146. Reservoir sedimentation.--Irrigation reservoirs on the Pecos River furnish ample evidence that sediment depletes storage capacity and shortens the life of these facilities. McMillan Dam was built in 1894. With its original capacity 67 percent depleted, it is practically useless as a storage reservoir, but it does serve as a regulator of irrigation water. An extensive area of salt cedar at the head of Lake McMillan provides a natural sediment trap. About 22,000 acre-feet of sediment have accumulated in the salt cedar area, and the life of Lake McMillan has been prolonged. The thick vegetative growth is consuming about 70,000 acre-feet of water annually. This water is needed for irrigation downstream. Although proof is not available, there is evidence that the area of salt cedar aggravates flood problems upstream. The river at Lake Arthur was only a mile wide during the 1904 flood, whereas it was six or seven miles wide in 1937 when the flood peak was lower. It has been estimated that the river bed at the Dayton gauging station has risen 8 feet in about 35 years. Much of the economy of the Pecos Valley is dependent upon irrigation. Irrigation in turn is dependent upon water storage. Storage depends on suitable reservoir sites, and reservoir sites are limited. Protection of existing reservoirs and reservoir sites is a prime requisite for a continued prosperous agriculture in much of the valley.

147. Evaluation of flood damages.--All monetary expressions of damages are based on 1948 price levels. They include only capital losses, increases in expenses, and decreases in income caused by floodwaters or damages arising therefrom. In the latter category are indirect damages, only two of which have been evaluated: 1) reductions in crop production because of interrupted irrigation services, and 2)

detouring costs associated with highway damage. If sufficient data were available to evaluate other indirect damages, the estimate of monetary loss caused by floods would probably be much greater.

148. Field surveys and secondary sources of information offer a reliable basis for estimating flood damages in the watershed since 1932. Relationships between peak discharges and flood damages have been established on the basis of past experience. Those relationships were used for estimating damages from known or calculated discharges. Floods have occurred during 11 of the last 15 years. In 1941, two major floods occurred. Even in the abnormally dry year of 1934, the Rio Bonito and Rio Hondo were in flood stage.

149. Future floodwater damages.—This analysis is based on floodwater damages which are expected to occur under present watershed conditions. The extent to which the continuation of "going" programs will improve watershed conditions and reduce floodwater and sediment damages is taken into account in the estimate of benefits of the recommended program.

150. Frequency of future floods.—Based upon past flood and rainfall records it is estimated that floods of sufficient magnitude to cause damage throughout the watershed occur once in every 3 to 5 years. Frequencies of peak discharges at selected gauging stations were used for estimating flood damages.

151. Calculation of average annual floodwater damages.—An examination of floodwater damage data and peak discharge records at appropriate gauging stations indicates that the amount of damage is closely associated with the peak discharge. The relationships between experienced floodwater damages and peak discharges for floods on which information is available was used to calculate damage from floods of a normal frequency series as developed by the hydrologists. To illustrate the methodology, the reach of the Pecos River from Alamogordo Dam to Highway 380 east of Roswell is used as an example. Estimates of damages for three floods are available and are as follows (1948 price levels):

Year of Flood	Peak Discharge (Guadalupe Gauge) cfs	Total Monetary Damage
1937	23,200	$122,000
1941	40,100	380,000
1942	42,800	431,000

The above estimates of flood damage do not include damage to land due to stream bank erosion. This type of damage is more closely associated with duration of flow and flood volume than flood peak and is considered subsequently.

152. Based on the above peak-damage relationships, the damage for each flood in the normal frequency series was calculated as follows:

Percent of years that peak flow is equaled or exceeded	Peak Discharge (cfs)1/	Calculated Damage
20	18,000	$ 32,200
10	27,000	178,000
4	41,000	403,000
2	52,000	580,000
1	64,000	775,000

1/ Period of record used to calculate peak discharge was 1931-1943, 13 years - 6 years before and 7 years after Alamogordo Reservoir was built. This period was selected as being representative for damage evaluation purposes.

Floods of 16,000 cfs or less were considered nondamaging. The estimate of average annual floodwater damage was secured by multiplying the damage per flood by its average frequency. In this reach average annual damages exclusive of bank cutting were estimated at $45,700.

153. An examination of flood records indicates that damage to land by stream bank erosion is not necessarily associated with magnitude of flood peaks. In the Fort Sumner district, for example, during the 1937 flood, 100 acres of highly developed irrigated land caved into the Pecos River. In 1941, with a flood peak 70 percent higher, the acreage caved was only 60. However the flood flow during 1937 was considerably longer than during 1941. The number of days when the mean daily flow exceeded 1,500 cfs in 1937 was 19 and in 1941 was only 11. The rate of stream bank erosion was 5.3 acres per day in

1937 and 5.5 acres per day in 1941. This rate of erosion (5.4 acres per day) was applied to the normal flood frequency series, expressed in volume of flood flow to determine the average annual rate of stream bank erosion. Rates of stream bank erosion were similarly determined for other reaches of the main stream and tributaries. This resulted in the following estimates of annual cropland loss due to stream bank erosion:

Upper Pecos above Alamogordo	11	acres
Alamogordo to Roswell	15	"
Roswell to McMillan	21.5	"
Upper Hondo and tributaries	19.1	"
Total watershed	66.6	"

154. The above estimate includes only those areas where it appeared that stream bank protection structures are feasible to stop erosion. Other areas are subject to stream bank erosion but due to the low value of land being destroyed or the relatively low rate of lateral erosion, stream bank protection structures are infeasible.

155. In making a monetary evaluation of land damage due to stream bank erosion, the application of going land values to the acreage involved does not provide an adequate picture of damages incurred. Particularly is this true on the upper Pecos and upper Hondo where farm units are small and the possibility of subjugation of additional land is virtually nonexistent. For this reason estimates were made of future reductions in farm income due to stream bank erosion. These reductions were capitalized at a four percent interest rate to determine the capital loss incurred. Approximately 70 percent of the total land damage shown in table 10 is due to stream bank erosion.

156. Average annual floodwater damages.—Based on present watershed development and normal flood frequency, annual floodwater damages are estimated at $555,200 (table 10). Damage to land and growing crops make up over 60 percent of the total. No estimate was made of the amount of land damage occurring in the watershed outside of the flood plain areas. Channel incision and gullying in range areas is responsible for sizeable reductions in range productivity, but limitations of adequate data preclude accurate estimates of the monetary damage incurred. Eighty-nine percent of floodwater damages are sustained by agricultural interests. Although all indirect damages are not evaluated, they account for about 9 percent of the total.

157. Sedimentation damages.—Deposition of sediment that occurs primarily as a result of channel overflow has been evaluated as floodwater damages (table 10). Damage of this type includes deposition of sediment on agricultural lands, irrigation canals and ditches, drainage channels, rural improvements, and urban property. The effect of sedimentation on useful reservoir life and water supply is discussed in the following paragraphs.

Table 10 – SUMMARY OF ESTIMATED FUTURE AVERAGE ANNUAL FLOODWATER DAMAGES 1/

Pecos River Watershed

REACH OR TRIBUTARY	AGRICULTURAL DAMAGES						NON-AGRICULTURAL DAMAGES					TOTAL ANNUAL FLOOD-WATER DAMAGE
	Direct						Direct					
	Land	Crops	Irrig. Systems	Other	In-direct	Total	Trans-portation	Urban	Other	In-direct	Total	
PECOS RIVER	$	$	$	$	$	$	$	$	$	$	$	$
Above Alamo-gordo Res.	17,500	6,400	35,500	900	15,400	75,700	8,600	300	–	8,200	17,100	92,800
Alamogordo to Roswell	20,500	3,800	14,600	1,700	1,600	42,200	9,500	–	5,400	7,100	22,000	64,200
Roswell to Lake McMillan	56,900	84,500	2,800	10,600	–	154,800	1,400	–	–	1,300	2,700	157,500
McMillan to Red Bluff	300	2,300	700	200	500	4,000	300	200	600	100	1,200	5,200
Red Bluff to Girvin	6,600	33,600	1,100	1,700	300	43,300	4,700	800	4,000	900	10,400	53,700
Subtotal (P.R.)	101,800	130,600	54,700	15,100	17,800	320,000	24,500	1,300	10,000	17,600	53,400	373,400
TRIBUTARIES												
Rio Hondo												
Berrendo Creek	1,100	1,900	–	3,100	–	6,100	2,000	–	–	1,900	3,900	10,000
Rio Ruidoso	5,000	1,900	1,400	200	200	8,700	500	600	–	200	1,300	10,000
Rio Bonito	14,700	1,500	1,900	100	500	18,700	1,200	–	–	1,000	2,200	20,900
Rio Hondo above res.	18,500	15,100	5,100	1,200	1,800	41,700	600	–	–	600	1,200	42,900
Rio Hondo below reservoir was not evaluated.												
Subtotal (R.H.)	39,300	20,400	8,400	4,600	2,500	75,200	4,300	600	–	3,700	8,600	83,800
Rio Felix	1,300	2,200	–	3,500	–	7,000	2,300	–	–	2,200	4,500	11,500
Rio Penasco	8,600	5,600	700	600	300	15,800	1,500	–	–	800	2,300	18,100
Toyah Cr. & vic.	1,200	9,900	5,100	1,700	500	18,400	11,700	700	200	1,600	14,200	32,600
Other tribs.	2,700	9,500	3,400	2,200	700	18,500	5,200	9,500	800	1,800	17,300	35,800
Subtotal (Tribs.)	53,100	47,600	17,600	12,600	4,000	134,900	25,000	10,800	1,000	10,100	46,900	181,800
TOTAL WATERSHED	154,900	178,200	72,300	27,700	21,800	454,900	49,500	12,100	11,000	27,700	100,300	555,200

1/Based on 1948 price levels and assuming maintenance of present watershed conditions.

158. The problem of reservoir sedimentation.—Irrigation interests which depend upon reservoirs for water supply are confronted with the problem of storage depletion by sediment. Reservoirs of the Carlsbad project, including Alamogordo and McMillan, are being depleted by sediment at the rate of approximately 3,300 acre-feet per year. This rate of deposition includes the sediment deposited above crest in Lake McMillan, which does not deplete reservoir storage capacity but which does more damage than if the sediment were deposited in the reservoir pool. Conditions favorable to growth of salt cedar have developed above McMillan and to a lesser extent above Alamogordo on the sediment deposited above spillway crest. Salt cedar has spread over an area above Lake McMillan of approximately 14,000 acres. This vegetation consumes an excessive amount of water, and there is a high annual loss of water to irrigation interests. This is the chief damage that results from sediment deposits above McMillan Reservoir. As determined by a single reconnaissance survey, Red Bluff Reservoir on the Texas-New Mexico line is accumulating an estimated 1,600 acre-feet of sediment annually. This may be somewhat high but lacking other data, this figure is being used. The total amount of sediment being deposited each year in the three reservoirs is, therefore, estimated at 4,900 acre-feet. The estimated accumulation by reservoir is as follows: Alamogordo, 2,300 acre-feet; McMillan, 1,000 acre-feet; and Red Bluff, 1,600 acre-feet. It is probable that this loss of storage capacity can be replaced at alternative sites and irrigation projects dependent upon stored water can be operated for many years. However, in the process of filling reservoirs and replacing them, each abandoned reservoir becomes a heavy user of water by evaporation from sediment deposits, seepage, or transpiration by salt cedars. Conceivably, water supply rather than availability of reservoir sites might become the limiting factor in the maintenance of irrigation projects.

159. Method of estimating sediment damage to reservoirs.—Theoretically at least, there are three methods by which sediment damages can be estimated, depending on the basic hypothesis of future operations that are adopted:

1. It can be assumed that additional storage capacity will be developed each year to offset the loss of present capacity due to sediment deposition. In this case the sediment damage is equal to the cost of replacement as there will be no diminution of water supply of the dependent irrigation projects. On this basis the cost of replacement, or sediment damage, is estimated at about $200,000 per year. This, however, is based on a highly theoretical assumption — one that never exists in fact. Reservoir capacity cannot be developed by a series of

small accretions. And if history furnishes any criteria, replacement capacity is not constructed until the pinch of water shortages becomes acute. For these reasons this method of estimating sediment damages has been discarded.

2. It can be assumed that the development of additional reservoir sites is infeasible. Under this assumption the acreage irrigated by stored water would gradually shrink to zero as the reservoirs are filled with sediment. The annual sedimentation damages are equal to the difference in services supplied by the reservoirs with no sediment and the annual equivalent value of a declining series of values from present levels to zero. This method results in an estimate of sediment damages of $500,000 annually. The principal weakness of this estimate lies in the basic assumption that reservoir replacement is infeasible. There is considerable evidence at hand to indicate that it is feasible to replace present reservoirs at least once on the basis of present methods of economic justification.

3. It can be assumed that reservoir capacity will be replaced sometime before the entire capacity is lost but sometime after sediment displacement causes a reduction in the water supply. This essentially is a compromise of the first two assumptions. Because it is more realistic than the first two assumptions, it is used as the basis for estimating damages to irrigation reservoirs. The average annual sediment damage to reservoirs using this method is estimated at $377,800. The method used in arriving at this estimate is discussed in the following paragraphs.

160. As pointed out above, the damage to a reservoir is made up of two types of damage: 1) the damage to the reservoir itself arising from the fact that sediment shortens its useful life and thereby necessitates frequent replacement at additional cost and 2) the reduction in services supplied by the reservoir between the time that capacity depletion begins to affect the water supply and the time replacement is made. Furthermore, there is a point in the life of any reservoir, depending upon the rate of capacity depletion, the cost of replacement, and the value of water, when it is most economical to replace the reservoir and thereby minimize costs or damages. This is merely based on a well recognized principle of cost accounting. Decisions on when to replace equipment, or a factory for example, are based on the same principles.

161. In order to determine the minimum sediment damage or the minimum cost of maintaining water supply, these three factors were determined:

1. The cost of replacement storage.

2. The productive value of water.

3. The effect of sediment deposition or reduced reservoir capacity on water supply.

162. Cost of replacement storage.—No cost estimates of alternative reservoirs, based on detailed surveys, are available. Some rough cost estimates of apparently suitable sites have been made. That these estimates were apparently low is shown by the fact that at least one such site was passed up when Alamogordo Reservoir was built in 1936 at an indicated higher cost.

163. In the absence of any better data, a comparison of the cost of Alamogordo and McMillan Reservoirs was made. Alamogordo was built primarily to replace McMillan. When the original construction costs were placed on a comparable cost basis, it was found that Alamogordo exceeded the cost of McMillan by slightly more than 50 percent (per acre-foot). On this basis it was assumed that replacement for Alamogordo would in turn cost 50 percent more than Alamogordo. As a matter of fact the additional cost of developing less favorable sites represents only a small part of the total additional cost. Replacement sites are generally located upstream from existing developments, each one farther away from the land it serves. Operational losses increase, greater storage capacity is required to provide the same amount of irrigation water, and the farther upstream irrigation reservoirs are located, the more water is allowed to escape unused from the basin. Thus it should be obvious that the use of an estimated cost of replacement 50 percent greater than the cost of present reservoirs is amply conservative.

164. The productive value of water.—Throughout the Pecos River watershed and particularly in those areas irrigated by reservoirs, water is the limiting factor of production during most years. Reduction of reservoir capacity by sedimentation further limits water supply with a consequent reduction in crop yields and/or curtailment of crop acreages. As a result farm income decreases. The extent to which net farm income decreases is considered a damage attributable to reservoir sedimentation. The productive value of water is defined as the reduction in net farm income per acre-foot of water supply lost due to reservoir sedimentation.

165. The extent to which net farm income is reduced depends to a considerable degree on the adjustments farmers make to meet the requirements of reduced water supply. Temporarily, they may shift to crops that require less water. Alfalfa has a high water requirement, but it is extremely doubtful if yields of other crops can be maintained without alfalfa in the rotation. Cotton, with a relatively low water requirement, is limited by acreage allotments. Another alternative is to spread the reduced water supply over the same acreage. However, this would result in great reductions in crop yields with very little reduction in operating costs. The third alternative and the one that would probably minimize losses is to reduce the acreage irrigated. On this basis it is estimated that the reduction in net farm income amounts to about $15.90 per acre-foot of water. This is considered the productive value of water (1948 conditions).

166. The effect of sediment on water supply.—Because storage reservoirs spill only occasionally, an acre-foot of sediment does not displace an acre-foot of water annually. The amount of displacement at various levels of capacity depletion was determined by reservoir operation studies, using available records of inflow, river depletions, and irrigation requirements consistent with available supply. The relationship between available storage capacity and water supply is not the same for different reservoirs nor is it constant throughout the life of the reservoir. As a reservoir fills with sediment, spills become larger and more frequent, and each acre-foot of sediment reduces the water supply more and more. At Alamogordo Reservoir, for example, it was found that after 10 years of sedimentation at present rates, water supply is reduced by only 1,900 acre-feet annually, in 20 years the reduction is 4,200 acre-feet, and after 40 years it amounts to 10,600 acre-feet.

167. Annual sedimentation damage to reservoirs.—On the basis of replacement cost and value of water lost as a result of sedimentation, average annual sedimentation damages were determined for Alamogordo and Red Bluff Reservoirs. A brief excerpt of the tabulation for the Alamogordo Reservoir is shown below to illustrate the method used.

SEDIMENTATION DAMAGES - ALAMOGORDO RESERVOIR

Given: Sedimentation rate 2,300 acre-feet per year.
Cost of replacement $6,140,000
Value of water $15.75 per acre-foot. 1/

Age of reservoir	Annual cost of replacement 2/	Value of water lost annually	Total sediment damage
44 years	$78,200	$81,900	$160,100
45 years	75,300	84,600	159,900
46 years	72,600	87,300	159,900
47 years	70,000	90,100	160,100

1/ Value of $15.75 per acre-foot applies only to water stored in Alamogordo Reservoir. The average value of stored water in all reservoirs is $15.90 per acre-foot (1948 price levels).

2/ Annuity necessary to accumulate replacement cost at 2½ percent interest at the end of period shown in left hand column.

168. The foregoing tabulation indicates that, under the hypotheses used, replacement of Alamogordo Reservoir should be made when it is 45 or 46 years old and that the total sediment damage is estimated at $159,900 per year. This amounts to a damage of about $70 per acre-foot of sediment. The damage to Red Bluff Reservoir was similarly calculated. The damage to this reservoir is estimated at about $81 per acre-foot of sediment.

169. Sedimentation of Red Bluff and Alamogordo Reservoirs represents about 80 percent of the total reservoir sedimentation in the watershed for which damages are evaluated. Accordingly the mean sediment damage per acre-foot of sediment for Alamogordo and Red Bluff Reservoirs was applied to the other reservoirs. On this basis, total reservoir sedimentation damages are estimated at $377,800 annually.

170. Summary of average annual flood damages.—Under present conditions, it is expected that flood damages will average $933,000 annually, as shown in table 11.

Table 11 - SUMMARY OF AVERAGE ANNUAL FLOOD DAMAGES

Pecos River Watershed

Type of Damage	Amount	Percent of Total
Floodwater damage		
Agricultural		
Land	$154,900	16.6
Crops	178,200	19.1
Other	121,800	13.1
Nonagricultural	100,300	10.7
Subtotal - Floodwater damage	555,200	59.5
Sediment damage	377,800	40.5
TOTAL FLOOD DAMAGE	$933,000	100.0

171. Other flood damages not evaluated.—Certain flood damages are not adaptable to monetary evaluation either because of their nature or because sufficient data are not available to evaluate them. Some of the more important damages of this type are:

a. Loss of meadow land (not included in table 10) by bank caving and lowering of water table. This land forms the hub of many ranch operations. Its destruction creates a damage far in excess of the normal market value of the land.

b. Loss of range improvements. Because of their scattered nature, destruction of range improvements caused by floods was not evaluated. The principal improvements affected are fences, water spreaders, and stock tanks, either by sedimentation or actual destruction.

c. Loss of range livestock. Flood producing storms, especially the short, high intensity storms, drive livestock into arroyas where the high banks offer a measure of protection. There they are trapped and drowned by walls of water rushing down the channel. Eye-witness accounts frequently mention drowned livestock floating in the floodwaters.

d. Loss of life. During the 1941 flood year, at least 23 people are known to have lost their lives.

e. Interruption of business activity. Floods naturally interfere with normal business activity both on the farm and in the city. The economic value of the interruption of normal business activity is real though difficult, if not impossible, to evaluate.

f. Costs of evacuation. Floods, or threats of floods, often lead to widespread evacuation of flood zones. This is a common occurrence in Roswell, New Mexico. A number of families were evacuated from their homes in the village of Lake Arthur, New Mexico, during the flood of 1945.

g. Decreased water supply due to channel enlargement or aggradation. The increase in channel losses brought about by enlargement due to floods has undoubtedly resulted in less water being available for beneficial uses. With the increase in channel capacities, losses by evaporation and transpiration are robbing irrigation interests of much needed water. The Pecos River at the head of Lake McMillan is estimated to be seven times as wide in 1941 as it was in 1904. Similar differences have probably developed in other areas.

h. Unsanitary living conditions following floods. Opportunities abound for widespread epidemics following floods. Open wells and irrigation ditches are the source of much of the domestic water and are highly subject to contamination and pollution. Flooded basements are another menace to health.

RECOMMENDED PROGRAM

172. General.--The program of runoff and waterflow retardation and soil erosion prevention recommended in this report has been developed along lines proposed by Federal, state, and local agencies interested in program objectives. In addition, some phases of the program are based on studies of representative sample watersheds. Investigations were made in small watersheds to determine the kind and extent of special flood control measures needed to reduce floodwater damage and stream bank erosion.

Land Treatment Measures

173. General.—Many of the land treatment measures recommended are now being carried out in the watershed by several agencies which conduct programs that include, or contribute to, the establishment of soil and moisture conservation practices. The work being done by these agencies which contributes to a reduction in floodwater and sediment damages in the watershed has been considered in the development of program recommendations. Each agency has provided information regarding the quantities and Federal cost of practices being established currently which contribute to flood control objectives. It is assumed that these activities will continue at present rates. The quantities of land treatment measures recommended herein represent the additional quantities of measures needed over and above the amounts that will be applied during the 15-year installation period at current rates.

174. Range and forest land improvement.—The improvement of deteriorated cover on range and forest lands in the watershed is a fundamental part of the program herein recommended. The following recommended practices will aid in retarding runoff, reduce rates of erosion and sedimentation, and increase the over-all productivity of grazing and timber lands. Natural revegetation will be relied upon for most of the rehabilitation of watershed lands. This will be brought about through improved management practices including conservative forage utilization, improvement of systems of grazing, and other practices which will allow for better distribution of livestock and eliminate concentration of use. Depleted range land will be seeded to grass where conditions are favorable for establishing a grass cover. The seeding of some areas will involve brush removal. Cultivated land not suited for crop production will be seeded to grass for grazing use. Seeded areas will need to be protected from grazing until the grass cover becomes established. Rodents will be controlled in areas to be seeded and in localized areas in the watershed to aid in establishing and maintaining a satisfactory vegetative cover. Secondary roads throughout the watershed will be treated at locations where erosion is critical. Much of the road stabilization work will be done in the forested portions of the watershed.

175. In addition to the foregoing measures, structural measures recommended to aid in improving watershed conditions include diversion dams, dikes, ditches, and grade stabilization structures.

176. The application of additional fire control measures will reduce the incidence and extent of timber and grass fires and thereby reduce the area that becomes a source of increased runoff and sediment production each year because of fires.

177. Land acquisition.—Numerous tracts of private lands within and adjacent to national forests present a problem in obtaining uniform application of a watershed improvement program. Much of the grazing land is abused by overgrazing. Some owners of timberlands cooperate with the Forest Service in setting good management standards for harvesting timber and disposing of slash. Other owners are not interested in carrying out these practices to preserve watershed resources. Clear cutting of timberlands creates an immediate flood hazard. Present high prices of lumber invite private owners to clear-cut timberlands without regard to the consequences of such wasteful operations. It is recommended that about 60,000 acres of privately owned land within or adjacent to national forests which are or may become critical flood source areas be purchased. Included are tracts which cannot be brought under conservative management for watershed protection while in private ownership. Land used for crop production under good management, homesites, and townsites have not been considered for purchase. Consequently, the proposed purchase program will not displace families.

178. Land treatment measures herein recommended are summarized in table 12.

179. Dry-farm land improvement.—Severe erosion is occurring on the dry-farm land in the upper portion of the watershed where steep slopes are cultivated. The soils are very erodible, and farming practices are conducive to rapid runoff and soil erosion. A number of conservation practices can be applied to these lands to reduce runoff and sediment production from such areas. These practices are: contour tillage, crop residue management, terracing, and retirement from cultivation of land that should not be farmed (table 12). Land retired from cultivation will be seeded to grass and protected from use until a vegetative cover is well established.

180. Irrigated land improvement.—About 50,000 acres of irrigated land in the watershed are the source of excessive runoff and sediment. This land is situated in the upper reaches of the Pecos River and its principal tributaries. All of the land should be leveled to reduce erosion and additional measures are needed to protect the land and conserve water. These measures include drops, water disposal systems, and suitable practices of water management. The remaining 225,000 acres of irrigated land in the Pecos Valley are not subject to serious erosion, but certain conservation measures will be applied to effect savings of water. This work will be carried out under the "going programs." The kind and amount of practices needed on irrigated land are shown in table 12.

Table 12 - ESTIMATED COST OF INSTALLING THE RECOMMENDED PROGRAM (1948 PRICES)

Pecos River Watershed

Measure	Unit	Number of Units	Federal Cost	Non-Federal Cost Public 1/	Non-Federal Cost Private	Total Cost
			$	$	$	$
LAND TREATMENT MEASURES						
Non-Federal Land (range and forest)						
1. Stabilizing and sediment control structures	number	18,500	2,239,500	-	2,015,500	4,255,000
2. Range improvement						
a. Grass seeding	acre	150,000	789,500	-	710,500	1,500,000
b. Rodent control	acre	200,000	35,000	35,000	-	70,000
3. Road erosion control	mile	1,600	80,000	80,000	-	160,000
4. Diversion dikes and ditches	mile	200	26,300	-	23,700	50,000
5. Fire control	acre	130,000	20,000	12,000	8,000	40,000
Subtotal			3,190,300	127,000	2,757,700	6,075,000
Non-Federal Land (dry farm)						
1. Diversion dikes and ditches	mile	1,000	80,500	-	72,500	153,000
2. Terracing	mile	2,700	202,700	-	182,300	385,000
3. Crop residue management	acre	24,000	22,700	-	20,500	43,200
4. Grassed waterways	acre	2,000	46,300	-	41,700	88,000
Subtotal			352,200		317,000	669,200
Non-Federal Land (irrigated)						
1. Leveling	acre	45,000	1,421,000	-	1,279,000	2,700,000
2. Erosion control structures	number	500	197,400	-	177,600	375,000
3. Diversion dikes and ditches	mile	1,300	104,800	-	94,200	199,000
Subtotal			1,723,200		1,550,800	3,274,000
TOTAL - Non-Federal Land			5,265,700	127,000	4,625,500	10,018,200

1/ State and local governments, their departments and legal subdivisions.

Table 12 — Continued

Measure	Unit	Number of Units	Federal Cost	Non-Federal Cost Public	Non-Federal Cost Private	Total Cost
			$	$	$	$
LAND TREATMENT MEASURES — Continued						
Federal Land (range and forest) 1/						
1. Stabilizing and sediment control structures	number	10,000	760,500	—	54,500	815,000
2. Range improvement						
a. Seeding grass	acre	32,000	242,300	—	23,700	266,000
b. Stock tanks	number	53	40,000	—	—	40,000
c. Wells	number	60	331,600	—	28,400	360,000
b. Fencing	mile	685	422,300	—	22,700	445,000
e. Rodent control	acre	178,125	62,200	—	—	62,200
3. Road erosion control	mile	625	61,000	—	—	61,000
4. Diversion dikes and ditches	mile	215	31,500	—	—	31,500
5. Work roads	mile	30	13,500	—	—	13,500
6. Fire control	acre	3,739,200	553,800	—	—	553,800
7. Land acquisition	acre	60,000	300,000	—	—	300,000
Subtotal			2,818,700	—	129,300	2,948,000
Federal land (dry farm) 2/						
1. Diversion dikes and ditches	mile	14	1,100	—	1,000	2,100
2. Terracing	mile	55	4,100	—	3,700	7,800
3. Grassed waterways	acre	50	1,200	—	1,000	2,200
Subtotal			6,400	—	5,700	12,100
Total — Federal land			2,825,100		135,000 3/	2,960,100
Total — Non-Federal land			5,265,700	127,000	4,625,500	10,018,200
Technical services — Federal land			674,000			674,000
Technical services — Non Federal land			2,866,000			2,866,000
Educational assistance			225,000	225,000		450,000 3540
Program evaluation			100,000			100,000
TOTAL — LAND TREATMENT MEASURES			11,955,800 4/	352,000	4,760,500	17,068,300

1/ Includes lands federally owned or administered.
2/ Mescalero Indian Reservation.
3/ Contributions by Mescalero Indians.
4/ Includes $513,200 for administration of direct aids.

Table 12 - Continued

Measure	Unit	Number of Units	Federal Cost	Non-Federal Cost Public	Non-Federal Cost Private	Total Cost
			$	$	$	$
ADDITIONAL MEASURES NEEDED FOR THE REDUCTION OF FLOODS AND SEDIMENT						
1. Channel improvement 1/	mile	2.5	136,000	16,000	21,000	173,000
2. Streambank protection 2/	mile	45.5	983,000		124,000	1,107,000
3. Floodway system 3/	mile	14	289,000		36,000	325,000
4. Detention structure	number	1	370,000		33,000	403,000
Subtotal			1,778,000	16,000	214,000	2,008,000
WATER CONSERVATION MEASURES						
1. Salt cedar eradication and control	acre	14,000	950,000	20,000	80,000	1,050,000
GRAND TOTAL			14,683,800	388,000	5,054,500	20,126,300

1/ Channel improvement: In Texas, channel changes to protect the Barstow diversion dam and improvement of Toyah Creek channel near Saragosa, Texas; in New Mexico, channel improvements in the vicinity of Pecos, New Mexico.

2/ Streambank protection: All in New Mexico. Pecos River above Alamogordo Reservoir, 3.3 mi.; Fort Sumner, 7.2 mi.; Roswell to Carlsbad, 15 mi.; Rio Hondo and tributaries, 20 mi.

3/ Floodway systems: All in N.M. - Upper Pecos, 10 mi.; Rio Hondo, 4 mi. This measure includes construction or enlargement of waterways, construction of detention structures, and alteration of irrigation facilities which cross arroyos.

TABLE 12A DISTRIBUTION OF THE ESTIMATED INSTALLATION COST OF LAND TREATMENT MEASURES ON THE PECOS RIVER WATERSHED

MEASURE	UNIT	NON-FEDERAL LAND: STATE AND PRIVATE: NUMBER OF UNITS	NON-FEDERAL LAND: STATE AND PRIVATE: FEDERAL COST	NON-FEDERAL LAND: STATE AND PRIVATE: NON-FEDERAL COST	NON-FEDERAL LAND: STATE AND PRIVATE: TOTAL COST	FEDERALLY OWNED OR ADMINISTERED LAND: PUBLIC DOMAIN: NUMBER OF UNITS	PUBLIC DOMAIN: FEDERAL COST	NATIONAL FORESTS: NUMBER OF UNITS	NATIONAL FORESTS: FEDERAL COST	INDIAN LAND: NUMBER OF UNITS	INDIAN LAND: FEDERAL COST	INDIAN LAND: NON-FEDERAL COST	INDIAN LAND: TOTAL COST	TOTAL PROGRAM COST: TOTAL FEDERAL	TOTAL PROGRAM COST: TOTAL NON-FEDERAL	TOTAL PROGRAM COST: TOTAL COST
NEW MEXICO																
RANGE AND FOREST LAND																
1. Stabilizing & Sediment Control Structures	Number	11,000	$1,331,600	$1,198,400	$2,530,000	1,500	$ 300,000	8,000	$ 400,000	500	$ 60,500	$ 54,500	$ 115,000	$2,092,100	$1,252,900	$3,345,000
2. Grass Seeding	Acres	50,000	263,200	236,800	500,000	8,000	64,000	19,000	152,000	5,000	26,300	23,700	50,000	505,500	260,500	766,000
3. Stock Tanks	Number	--	--	--	--	30	22,500	23	17,500	--	--	--	--	40,000	--	40,000
4. Wells	Number	--	--	--	--	50	300,000	--	--	10	31,600	28,400	60,000	331,600	28,400	360,000
5. Fencing	Miles	--	--	--	--	200	124,800	410	272,200	75	25,300	22,700	48,000	422,300	22,700	445,000
6. Rodent Control	Acres	100,000	17,500	17,500	35,000	100,000	35,000	73,125	25,500	5,000	1,700	--	1,700	79,700	17,500	97,200
7. Road Erosion Control	Miles	500	42,000	42,000	84,000	150	15,000	360	34,500	115	11,500	--	11,500	103,000	42,000	145,000
8. Diversion Dikes and Ditches	Miles	--	--	--	--	100	15,000	115	16,500	--	--	--	--	31,500	--	31,500
9. Work Roads	Miles	--	--	--	--	--	--	30	13,500	--	--	--	--	13,500	--	13,500
10. Fire Control	Acres	130,000	20,000	20,000	40,000	2,228,480	25,000	--	458,800	200,000	70,000	--	70,000	573,800	20,000	593,800
11. Land Acquisition	Acres	--	--	--	--	--	--	60,000 1/	300,000	--	--	--	--	300,000	--	300,000
12. Technical Services	--	--	940,800	--	940,800	--	365,600	1,217,120	215,700	--	81,200	--	81,200	1,603,300	--	1,603,300
Total			2,615,100	1,514,700	4,129,800		1,266,900		1,906,200		308,100	129,300	437,400	6,096,300	1,644,000	7,740,300
CULTIVATED LAND -- DRY FARM																
1. Diversion Dikes and Ditches	Miles	1,000	80,600	72,500	153,000	--	--	--	--	14	1,100	1,000	2,100	81,600	73,500	155,100
2. Terracing	Miles	2,700	202,700	182,300	385,000	--	--	--	--	55	4,100	3,700	7,800	206,800	186,000	392,800
3. Crop Residue Management	Acres	24,000	22,700	20,500	43,200	--	--	--	--	--	--	--	--	22,700	20,500	43,200
4. Grassed Waterways	Acres	2,000	46,300	41,700	88,000	--	--	--	--	50	1,200	1,000	2,200	47,500	42,700	90,200
5. Technical Services	--	--	406,200	--	406,200	--	--	--	--	--	11,500	--	11,500	417,700	--	417,700
Total			758,400	317,000	1,075,400						17,900	5,700	23,600	776,300	322,700	1,099,000
CULTIVATED LAND -- IRRIGATED																
1. Leveling	Acres	45,000	1,421,000	1,279,000	2,700,000	--	--	--	--	--	--	--	--	1,421,000	1,279,000	2,700,000
2. Erosion Control Structures	Number	500	197,400	177,600	375,000	--	--	--	--	--	--	--	--	197,400	177,600	375,000
3. Diversion Dikes	Miles	1,300	104,800	94,200	199,000	--	--	--	--	--	--	--	--	104,800	94,200	199,000
4. Technical Services	--	--	693,000	--	693,000	--	--	--	--	--	--	--	--	693,000	--	693,000
Total			2,416,200	1,550,800	3,967,000									2,416,200	1,550,800	3,967,000
Total - New Mexico			$5,789,700 2/	$3,382,500	$9,172,200		$1,266,900		$1,906,200		$326,000	$135,000	$461,000	$9,288,800	$3,517,500	$12,806,300
TEXAS																
RANGE AND FOREST LAND																
1. Stabilizing & Sediment Control Structures	Number	2,000	907,900	817,100	1,725,000	--	--	--	--	--	--	--	--	907,900	817,100	1,725,000
2. Grass Seeding	Acres	100,000	526,300	473,700	1,000,000	--	--	--	--	--	--	--	--	526,300	473,700	1,000,000
3. Rodent Control	Acres	100,000	17,500	17,500	35,000	--	--	--	--	--	--	--	--	17,500	17,500	35,000
4. Road Erosion Control	Miles	760	38,000	38,000	76,000	--	--	--	--	--	--	--	--	38,000	38,000	76,000
5. Diversion Dikes and Ditches	Miles	200	26,300	23,700	50,000	--	--	--	--	--	--	--	--	26,300	23,700	50,000
6. Technical Services	--	--	826,000		826,000	--	--	--	--	--	--	--	--	826,000	--	826,000
Total - Texas			$2,342,000 3/	$1,370,000	$3,712,000									$2,342,000	$1,370,000	$3,712,000
Educational Assistance														225,000	225,000	450,000 4/
Program Evaluation														100,000	--	100,000
TOTAL - WATERSHED			$8,131,700	$4,752,500	$12,884,200		$1,266,900		$1,906,200		$326,000	$135,000	$461,000	$11,955,800	$5,112,500	$17,068,300

1/ Private lands to be acquired. 2/, 3/ includes $367,200 and $146,000 respectively for administration of direct aids. 4/ New Mexico, $337,500; Texas, $112,500.

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Technical Services - Direct Aids - Educational Assistance

181. Technical services.—Technical services will be provided to plan and apply the land treatment measures herein recommended. The cost of technical services is shown in table 12. These services will be furnished to plan proper land management practices which are necessary for vegetative improvement in the watershed. They include the planning of suitable conservation measures on dry-farm and irrigated land to control runoff and reduce erosion. Measures recommended are terracing, crop residue management, grassed waterways, land leveling, and diversion dikes and ditches. Technical services include the engineering help needed to design and construct stabilizing and sediment control structures. The services needed to apply measures recommended for forest, range land, and woodland areas will also be furnished.

182. Direct aids.—A share of the cost of installing land treatment measures on non-Federal land will be contributed in the form of direct aids to individuals who participate in the program. The part of cost of the installation of approved measures which will be covered by direct aids is distributed among land treatment measures listed in table 12. Land operators will contribute a substantial part of the cost of installing measures on non-Federal land. Because of the extreme differences in financial ability of land operators to apply recommended measures and due to the extent of public benefits involved, there needs to be considerable flexibility in the direct aid program.

183. Educational assistance.—Landowners and operators and others in the watershed will be furnished educational assistance relative to the need for the recommended program and its purposes and objectives. Information will be supplied as to the manner in which landowners and operators now obtain services and assistance that are available through the various governmental agencies, and how they can and should, by their own efforts, contribute successfully and most economically to the accomplishment of the over-all objectives. Intensified educational efforts will be directed to familiarizing farmers with the specific practices and measures essential to runoff and waterflow retardation and soil erosion prevention, how to install and apply those measures not requiring the detailed assistance of a specialized technician, how to maintain such installations and measures, and how to integrate all into the soundest farming system to produce the greatest benefit over a long period of time. The Department is committed to a watershed and subwatershed approach in carrying out its responsibilities in the interest of flood control. It is essential that educational assistance provided under this program be directed toward furthering the specific objectives of floodwater and

sediment damage reduction, and that it be fitted as to method and synchronization into subwatershed operations activities.

183a <u>Program evaluation</u>.—Investigations and studies of program installations will be conducted in selected subwatersheds to determine their effectiveness and adequacy for runoff and waterflow retardation and soil erosion prevention. To implement these activities, it may be necessary to provide devices to measure rainfall and stream flow in the areas where program evaluations are made. The results of the studies may indicate changes needed in the application of land treatment measures to make the program more effective in reducing floodwater and sediment damages. They will also be used to evaluate the effect of the program on watershed yields.

Additional Measures Needed for the Reduction of Floods and Sediment

184. Channel improvement.--Some reaches of the Pecos and major tributaries have constricted channels so that small flood flows cause extensive damage by overbank flooding. At other points the channel alignment retards flood flows, and adjacent areas are damaged by overflow when floods occur. As a means of regulating flood flows, the channels will be cleared, straightened, or enlarged to the extent necessary to prevent overbank flooding. The amount of channel work recommended is indicated in table 12.

185. Bank protection.--The encroachment of the river or tributaries into irrigated land is serious in irrigated farming areas. Stream bank erosion has been dealt with by individuals at isolated points, but the cost of adequate protective measures is beyond their financial capacity. The program proposes the installation of stream bank protection structures at locations where there are extensive losses of irrigated land. Various kinds of materials will be used to stabilize stream banks. Maximum possible use will be made of local material so that costs will be kept as low as possible. In some construction, tree and cable will be used. Such materials as rock, wire, rails, or structural steel will be used in revetment works. The number of miles of stream bank protection work recommended is shown in table 12.

186. The estimated cost of measures designed to prevent stream bank erosion is based on the calculated cost of work near Fort Sumner, New Mexico, which consists of tree and cable revetment and/or tetrahedrons with tie-back silt depositor jetties in critical areas. These measures will be supplemented with selected tree and shrub plantings. Based on 1948 prices, the construction cost is estimated at $5.80 per foot. Stream bank protection work at Fort Sumner is an example of the more expensive type of treatment. The problem at some sites will be corrected with only tree and cable type of installations. This will reduce the average cost of stream bank protection work to an estimated $4.60 per foot.

187. Floodways.--Considering the entire area, water limits the expansion of irrigated agriculture in the watershed. However, in the upper reaches of the Pecos and its main tributaries, irrigable land is a limiting factor. The developed areas are narrow strips of land situated adjacent to channels where they can be irrigated readily with water diverted from streams. When this land is destroyed by floodwater or by the deposition of infertile material, it cannot be replaced by the development of new land. The shortage of irrigable land in the upper parts of the watershed has compelled farmers to encroach upon natural stream channels. To maintain the

acreage under cultivation, some farmers have eliminated the natural waterways. When floods occur, overflow is inevitable. Crops and land are damaged by floodwater, but sediment damage is the most serious problem in tributary drainages. The deposits of infertile material on irrigated land put it permanently out of production in some instances. Another type of damage caused by floods in side tributaries results from the sedimentation of main stream channels. The material washed into them fills the channel and changes stream flow so that flooding and bank cutting occur.

188. Irrigation ditches which serve the farm land are built across the side tributaries and are subject to damage when floods occur. If the structures are not washed out by high water, the irrigation ditch is filled with sediment which prevents operation of the system. Crops suffer when irrigation services stop. Other damages include cleaning or reconstruction costs. The recommended program includes the enlargement or construction of waterways, the construction of adequate irrigation facilities across the tributaries and the installation of overshots, detention structures, stabilized drops, and other structures to protect irrigation systems.

189. Irrigation structures which cross the drainageways obstruct the flood flows and are often damaged or destroyed. The floodway systems will include the installation of siphons in addition to detentions, channel enlargements, and stream bank stabilizations. The floodway systems will regulate flood flows and prevent damage to adjacent land. Interruptions in irrigation service will be prevented and crops will be protected from damage due to the lack of water.

190. The estimated cost of the 14 miles of floodways is based on a selected typical sample. A small tributary drainage of 1.37 sq.mi. and a 2,200-foot floodway through cultivated land near Villanueva, New Mexico, were studied in detail. This study revealed the most practical flood protection measure to be a detention dam above the cultivated land with an adequate floodway to carry the limited quantity of water discharged by the detention dam to the river without causing damage. The following data shows the basis for design and the estimated cost.

Estimated 100-year flood volume, present conditions	54.6 ac.ft.
Estimated 100-year flood volume, with program	38.2 ac.ft.
Estimated allowance for sediment expected to be deposited in reservoir the first 50 years	28.8 ac.ft.
Design capacity of detention dam	67.0 ac.ft.
Total height of earth fill detention dam	24 feet
Total earth fill	16,500 cu.yds.
Length of floodway to river	2,200 feet

Total estimated cost of floodway and detention with outlet and appurtenances	$9,520
Estimated number of floodways required	34
Estimated total cost of 14 miles of floodways	$325,000
Unit cost of floodways	$23,210 per mile

In this selected typical sample, a detention dam with a floodway was selected as being the best type of protection. In other cases existing floodways can be enlarged where the right of way required does not critically affect individual landowners. In some cases a detention dam with a diversion around the farm lands will be the most desirable plan. It is felt that this sample is typical and that for the purpose of determining the economic feasibility, the unit cost is on the conservative side.

191. Capitan detention dam.--An item in the recommended program is a detention structure on Salado Creek just above its confluence with Rio Bonita and about 2 miles below Capitan, New Mexico. This earth, rock-fill structure is designed to retard flood flows and reduce floodwater and erosion damage to high value irrigated land along the Rio Bonito and Rio Hondo.

Water Conservation Measure

192. Eradication and control of salt cedar.— Water supply is the limiting factor in the production of crops, as well as in many other activities, in the Pecos River Basin. The water yield under current conditions is fully appropriated for beneficial use on irrigated lands and for domestic use. Seasonal water shortages occur frequently, and the Pecos River Compact Commission has expressed concern regarding any type of program in the basin that might consume additional water. The Departments of Agriculture and Interior are anxious to assist in improving and maintaining water supplies to the greatest extent possible. So far as can be determined from available evidence and logical reasoning, an improvement in vegetative conditions throughout the Pecos River Basin will consume some additional water. This will be only a small percentage of the total water yield, but where there is not enough water now, even this small reduction would aggravate this critical situation. Under these circumstances, a complete program of watershed improvement should include enough water conservation measures to at least offset the estimated reduction in water yields.

193. Fortunately, in the Pecos Basin the small reduction in water yields expected as a result of carrying out a watershed improvement program can be offset by eliminating the salt cedar growth on the

delta area above McMillan Reservoir. The consumptive use of nonbeneficial salt cedars growing on the 14,000-acre delta area has been authoritatively estimated to average from 5 to 6 acre-feet per acre annually. This estimate includes precipitation and subsurface water consumed. A portion of this water can be salvaged by eradicating the salt cedars and maintaining the area in grass and other beneficial vegetation that consumes less water, thereby offsetting the anticipated reduction in runoff from certain portions of the watershed. It is therefore recommended that the salt cedars be eradicated and adapted grasses and other vegetation that consume less water be established on the area. Approximately 44 percent of the area to be treated is in Federal ownership and is administered by the Bureau of Reclamation. The remainder of the area is in private ownership. The program herein recommended for the delta area is not in conflict with other proposals being considered to conserve water and will be carried out by the Federal agencies concerned in cooperation with local interests. It is not intended to establish a principle regarding the allocation of water saved by carrying out this phase of the recommended program. The apportionment of salvaged waters between concerned states is covered by provisions of the Pecos River Compact. The responsibility of determining the location of use of salvaged waters rests with authorities of each state. Needs of established irrigation projects should receive first consideration in the division of salvaged water and distribution of any surplus water should be made on the basis of need for additional water and the relative benefit to be derived from its use.

194. The need for this type of work is recognized in article IV(a) of the Pecos River Compact, which states that: "New Mexico and Texas shall cooperate to support Legislation for authorization and construction of projects to eliminate nonbeneficial consupmtion of water." While this report includes only the recommendation for salt cedar control above McMillan Reservoir, the need for eliminating salt cedar growths throughout the basin where they are consuming water that could otherwise be put to beneficial use is fully recognized. In addition to the area above McMillan Reservoir, salt cedars are growing along the Pecos River from Alamogordo Reservoir downstream and are becoming a serious problem above Alamogordo, Avalon, and Red Bluff Reservoirs.

195. The installation cost of the salt cedar control program is estimated at $1,050,000 of which it is recommended that the Federal Government provide 90 percent and local interests the remaining 10 percent. Local interests will be expected to maintain the cover which is established to replace the salt cedar which it is estimated will cost about $35,000 annually.

196. The cost of clearing salt cedar is based on the estimated per acre cost of the following operations: clearing with machinery, $18; spraying regrowth with 2-4-D for three years, $15; planting grass and other adapted vegetation, $12; measuring results in water saving for a 5-year period, $5; contingencies and overhead, $25; total, $75 per year. Area to be treated 14,000 acres x $75 = $1,050,000.

197. A summary of all measures included in the recommended program is shown in table 12.

COSTS OF THE RECOMMENDED PROGRAM

Installation Costs

198. General.—The total installation cost of the proposed watershed treatment program is estimated to be $20,126,300. Of this amount the Federal Government will contribute approximately $14,683,800. State and local governments will be expected to contribute about $388,000, or its equivalent, and private interests will contribute some $5,054,500, or its equivalent. Table 12 shows a summary of the recommended program and the estimated costs to the Federal Government, state, and local governments, and private interests. Estimates of installation costs include work plan development, maintenance during the installation period, engineering and supervision, and overhead. Maintenance during the installation period includes the cost of necessary repairs to structures prior to transfer of the facilities to local agencies for operation. Administration cost involved in direct aids and cost of technical services are included in the cost of installing land treatment measures.

Operation and Maintenance Costs

199. General.—Operation and maintenance costs of the program are estimated at $337,840 annually (table 13). These costs are those involved in obtaining the maximum effectiveness of the program after the installation period. The maintenance of practices on Federal lands will be carried out at Federal cost. Measures carried out on non-Federal lands will be maintained by local interests.

Total Annual Costs

200. General.—The total cost of installing the proposed program is $20,126,300 (table 12), and the average annual installation cost is $578,975. The estimated average annual operation and maintenance cost of the program on the Pecos River watershed is $337,840. The total cost of the remedial program on an annual basis is $916,815. The Federal Government will contribute 63 percent of the average annual installation cost of the complete program and approximately 34 percent of the annual operation and maintenance cost.

Table 13 - ESTIMATED OPERATION AND MAINTENANCE COST OF THE RECOMMENDED PROGRAM

Pecos River Watershed

Measure	Unit	Number Units	Federal Cost	Non-Federal Cost Public	Non-Federal Cost Private	Total Cost (annual)
LAND TREATMENT MEASURES						
Non-Federal Land (range and forest)						
1. Stabil. & sed. control structures	no.	18,500			13,500	13,500
2. Grass seeding	ac.	150,000		500	2,000	2,500
3. Fire control	ac.	130,000	1,625	1,000	625	3,250
4. Road erosion control	mi.	1,600		8,000	-	8,000
5. Diversion dikes and ditches	mi.	200		60	210	270
Subtotal			1,625	9,560	16,335	27,520
Non-Federal Land (dry-farm land)						
1. Diversion dikes and ditches	mi.	1,000		300	1,100	1,400
2. Terracing	mi.	2,700			21,600	21,600
3. Grassed waterways	ac.	2,000			100	100
Subtotal				300	22,800	23,100
Non-Federal Land (irrigated)						
1. Leveling	ac.	45,000			90,000	90,000
2. Erosion control structures	no.	500			3,500	3,500
3. Diversion dikes and ditches	mi.	1,300		400	1,400	1,800
Subtotal				400	94,900	95,300
TOTAL - Non-Federal Land			1,625	10,260	134,035	145,920

Table 13 - Continued

Measure	Unit	Number Units	Federal Cost	Non-Federal Cost Public	Non-Federal Cost Private	Total Cost (annual)
LAND TREATMENT MEASURES - Continued						
Federal Land (range and forest)						
1. Stabilizing & sed. control structures	no.	10,000	$ 7,500	$ -	$ -	$ 7,500
2. Grass seeding	ac.	32,000	500	-	-	500
3. Stock tanks	no.	53	350	-	-	350
4. Wells	no.	60	1,000	-	-	1,000
5. Fencing	mi.	685	8,200	-	-	8,200
6. Road erosion control	mi.	625	3,000	-	-	3,000
7. Diversion dikes and ditches	mi.	215	300	-	-	300
8. Fire control	ac.	3,739,200 1/	93,500	-	-	93,500
Subtotal			114,350			114,350
Federal Land (dry farm)						
1. Diversion dikes and ditches	mi.	14			20	20
2. Terracing	ac.	55			440	440
Subtotal					460 2/	460
Total - Federal Land			114,350		460 2/	114,810
Total - Non-Federal Land			1,625	10,260	134,035	145,920
TOTAL - Land Treatment Measures			$115,975	$10,260	$134,495	$260,730

1/ Includes 129,000 acres privately owned timberland.
2/ Contribution by Mescalero Indians.

Table 13 - Continued

Measure	Unit	Number Units	Federal Cost	Non-Federal Cost		Total Cost (annual)
				Public	Private	
ADDITIONAL MEASURES NEEDED FOR THE REDUCTION OF FLOOD AND SEDIMENT DAMAGE						
1. Channel improvement	mi.	2.5	-	$ 320	$ 3,840	$ 4,160
2. Stream bank protection	mi.	45.5	-		31,000	31,000
3. Side arroyo control	mi.	14	-		4,800	4,800
4. Capitan detention dam	no.	1	-	2,150		2,150
Subtotal				2,470	39,640	42,110
WATER CONSERVATION MEASURES						
1. Salt cedar eradication				35,000		35,000
GRAND TOTAL			$115,975	$47,730	$174,135	$337,840

Annual Cost of Land Treatment Measures

201. General.—The cost of treating range, forest, irrigated, and dry lands varies widely. For analysis purposes, it is necessary to show the cost of installing and maintaining a land treatment program for each land use. The annual maintenance cost of watershed treatment by land use is shown in table 13.

Annual Cost of Measures Primarily for the Reduction of Floods and Sediment

202. General.—Although the measures primarily for the reduction of floods and sediment are to be installed at widely separated locations within the watershed, the unit cost of comparable practices do not vary greatly. Accordingly these measures have been grouped into four main categories: channel improvement, bank protection, floodway systems, and the Capitan detention dam. The total annual cost for the installation and maintenance of each measure is shown in table 13.

Annual Cost of Water Conservation Measures

203. General.—The eradication and control of nonbeneficial salt cedar which covers a 14,000-acre area above Lake McMillan will greatly reduce water consumption and make more water available for irrigation downstream. This water saving measure is included as a means of offsetting water losses due to the watershed treatment program. The annual cost of treating the salt cedar area is shown in table 13.

PROGRAM APPRAISAL

204. General.—It is estimated that portions of "going programs" of the Federal Government, together with the program recommended herein will reduce flood flows and sediment production by the amounts shown in the following paragraphs (205-222). These results and their effects on water yields and ground-water recharge are attributable to the combined programs. Methods of calculating the effects of the program are also shown.

205. Reduction of flood flows.—The reduction in precipitation excess due to the land treatment measures was calculated for each plant-soil group, and a weighted average reduction obtained for the selected representative watersheds (See par. 101). These reduced values were inserted into the peak discharge-volume curves and

the resultant peaks determined. The calculated reduction in run-off ranged from 29 percent on the Rio Bonita at Hondo to only 11 percent on Madera Canyon at Toyahvale, and averaged approximately 20 percent for the watershed as a whole. The average volume of flood flows will also be reduced by about 20 percent. The following example illustrates the method used in arriving at the estimated expected reductions in peak flows.

Example Calculations

Rio Felix at Hagerman - Drainage Area 932 sq. mi.

206. From the area occupied by each plant-soil group, the weighted average precipitation excess (surface run-off) for a typical 5-year frequency storm was calculated for present conditions and for future conditions with land treatment measures installed. Results are tabulated below.

Present conditions	P_e (precipitation excess)	=	0.58 in.
" "	Flood volume	=	17,970 ac.ft.
Future conditions w/program	P_e (precipitation excess)	=	0.46 in.
" " "	Flood volume	=	14,020 ac.ft.

From the equation of the peak-volume relationship (see par. 99), the peak flows for the above volumes are as follows:

Present conditions $P = .78 \times 17{,}970 + 926 = 15{,}000$ c.f.s.

Future conditions with program $P = .78 \times 14{,}020 + 926 = 11{,}900$ c.f.s.

Percent reduction in peak flow $= \dfrac{15{,}000 - 11{,}900}{15{,}000} = 20.7$ percent

207. In a similar manner the percent reduction in flood peaks was determined for the 10, 25, 50, and 100-year expected floods. These reductions were tabulated for all significant tributaries and for selected points along the Pecos River where needed for evaluating expected floodwater damage reduction.

208. Capitan detention dam.--The reservoir, which is expected to be fully effective for 100 years, is designed to control floods up to and including those of 100-year frequency. This reservoir, having a drainage area of 121 square miles, is located so that it will reduce flood damage along the Rio Bonito and Rio Hondo. The

effect of the range improvement measures, with and without the reservoir, was determined on the basis of flood volume reductions heretofore described. The result of this study is tabulated below.

Expected Flood Flows on Rio Bonito at Hondo

Frequency of Floods	Present Conditions		With Program	
	With Reservoir	Without Reservoir	With Reservoir	Without Reservoir
	cfs	cfs	cfs	cfs
5 yr.	3,000	5,900	1,900	3,500
10 yr.	4,400	8,600	2,800	5,300
25 yr.	6,200	12,200	4,000	7,800
50 yr.	7,800	14,900	4,900	9,700
100 yr.	8,800	17,400	5,900	11,600

Expected Flood Flows on Rio Hondo at Diamond A

5 yr.	3,800	4,200	3,000	3,300
10 yr.	6,600	7,400	5,400	6,000
25 yr.	11,700	13,400	9,500	10,800
50 yr.	17,100	19,900	13,500	15,500
100 yr.	24,800	28,600	18,400	21,100

209. Reduction of area flooded.—The area subject to flooding under present conditions is estimated to be 306,400 acres, of which 42,000 acres are irrigated cropland. Reductions in peak flood flows and additional flood protection provided by measures primarily for flood control will reduce the area subject to flooding by an estimated 96,000 acres. Of the total area protected from flooding, 23,000 acres are irrigated. In addition the frequency of flooding on the remaining acreage will be sharply reduced.

Effects of Land Treatment Measures

210. Changes in surface run-off.—In order to estimate the effect of the land treatment measures on irrigation water supply, it was necessary to divide the area above Red Bluff Reservoir into two categories: first, that portion in the mountains and forest from which large quantities of snow melt run-off occurs; and second, the lower lying areas which are made up almost entirely of range land and where surface run-off from rainfall predominates.

211. Within the high mountain portions of the watershed the intensity of program measures needed is less than on the lower lying areas, and consequently no significant change in run-off from the upper areas is expected.

212. A study of gauging station records shows that the annual yield of surface runoff from the lower lying areas of the watershed averages about 3.3 acre-feet. On the basis of infiltration data, it is estimated that the recommended land treatment measures will improve vegetative cover and may reduce annual surface run-off by about 20 percent or 0.66 acre-feet per square mile. The data used are the results of infiltration runs on range land, since the area considered is all grazing land with the exception of small, scattered tracts of cropland in the upper portions of the watershed. The area of cultivated land is so small its treatment will have virtually no effect on total surface run-off. On the basis of the anticipated change in run-off from range land due to vegetative improvement, the average annual yield above the Red Bluff project will be reduced by approximately 11,000 acre-feet.

213. Changes in soil zone run-off and ground-water storage.—In the area below the forest a portion of the additional water infiltrated into the soils will seep to established channels and discharge as "delayed surface run-off" or shallow "subsurface storm flow." 1/ The amount of water thus discharged will be influenced by the amount of rainfall, surface slope, the nature and thickness of the soil, and by the physical characteristics of the underlying geologic material. The following estimate of the portion of increased infiltration which may be expected to discharge from the soils developed upon the several formations in the area above Red Bluff Dam is based on consideration of these factors, and on results of watershed studies by the Forest Service. 2/

1/ Hydrology, Wisler, C. O. and Brater, E. F., John Wiley & Sons, 1949, p. 20.

2/ Annual Report of the Southwestern Forest and Range Experiment Station, 1946, p. 11.

Percent of Increased Infiltration Discharged	Geologic Formation and Age	Principal Constituents and Physical Characteristics of Formation
0 to 5	Alluvium, Quaternary	Silt, sand, gravel, unconsolidated permeable.
5 to 10	Ogallala, Tertiary	Alluvium, partially consolidated, ranges from somewhat permeable to permeable.
30 to 40	Pierre, Niobrara, and Dakota, Cretaceous	Shale, limey shale, limestone, sandstone, consolidated, bedded, relatively impermeable.
30	Dockum group, Triassic	Red shale, red to buff sandstone, consolidated, bedded, relatively impermeable.
10 to 15	Rustler and Castile formations, Carboniferous.	Limestone, gypsum, interbedded shale, consolidated, bedded, jointed, ranges from somewhat permeable to very permeable.
10 to 25	Chupadera and Abo formations, Carboniferous	Limestone, red shale, red sandstone consolidated, bedded, jointed, ranges from somewhat permeable to very permeable.
25	Magdalena group, Carboniferous	Limestone, gray and red shale, sandstone, consolidated, bedded, jointed, ranges from impermeable to permeable.
85	Igneous and metamorphic rocks, undifferentiated	Granite, impermeable except in fractured zones.

MAP 18

U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
PECOS RIVER WATERSHED
NEW MEXICO AND TEXAS

PUBLIC NO. 738 – 74TH CONGRESS
AS AMENDED JUNE 28, 1938
PUBLIC NO. 761 – 75TH CONGRESS

GROUNDWATER RECHARGE AREAS

SUBMITTED BY DHG APPROVED BY LDL
DATE 6-3-47 DATE 6-3-47

SOIL CONSERVATION SERVICE REGION 6

6-N-12984-A

Planning Board Joint Investigation, the results of which were published in 1942. As a water conservation compensatory measure, the report provides for the eradication of 14,000 acres of non-beneficial vegetation and certain accompanying land-use adjustments that will aid in maintaining the area free of nonbeneficial vegetation (par. 192). These land-use adjustments involve putting part of the area into desirable trees and shrubbery for wildlife as well as planting adaptable and desirable grasses for pasturage. With the eradication, control, and land-use adjustment, it is estimated that the consumptive use of this 14,000-acre area can be reduced by about 1½ acre-feet per acre per year, thereby releasing an estimated 21,000 acre-feet of water for beneficial use. The Bureau of Reclamation has prepared preliminary plans for by-passing a portion of the river flow around this delta area for water conservation purposes. The estimate of 1½ acre-feet per acre saving, however, was made in consultation with the Bureau, and there is no conflict or duplication in estimated water conservation benefits.

218. Effects of program on sediment production.—Corrective measures could do much to reduce or even stop sediment production. Protection of reservoir storage capacity, reducing erosion of range and cultivated lands, reduction of bank cutting, and halting of gully growth are all effectively done by proposed measures. Measures will necessarily vary in their effectiveness in controlling sediment. To control completely all types and sources of sediment contributed to the Pecos River would cost far more than could be justified. It is estimated that the land treatment and structural measures will reduce the erosion by the amount shown below.

Bank erosion, channel incision	25 percent of present rate
Large open gullies	50 percent of present rate
Sheet, rill, and small gully	45 percent of present rate

This would cause a reduction of gross movement of sediment of about 43 percent (table 14). At the prevailing high rates of sediment production, this is a large reduction in terms of volume.

219. The percentage of sediment eroded and which enters channels of all types to become stream load is about 91 percent of the total (table 14). This is roughly the equivalent of 16,010 acre-feet per year. The difference, about 1,521 acre-feet, represents deposits in fans, splays, plugs, colluvial basins, and other unclassified places of deposition.

Table 14 - EFFECT OF PROGRAM ON SEDIMENT PRODUCTION 1/

Pecos River Watershed

Type of Erosion	Percentage Total Sediment	Sediment Volume Present	Reduction w/program (rounded figures)	Reduction	Future Rate w/program
	percent	ac. ft.	percent	ac. ft.	ac. ft.
Sheet, rill	58.4	10,234 2/	45	4,564	5,670
Gullies, large	26.4	4,600	50	2,300	2,300
Bank cut, channel	15.2	2,697	25	674	2,023
Total	100.0	17,531		7,538	9,993

1/ Entire contributing basin.
2/ Consists of 8,713 acre-feet entering channels and 1,521 acre-feet of colluvium, wind eroded sediment, etc., not reaching channels.

220. Effects of program in reducing sedimentation in the larger reservoirs.-- The three largest reservoirs, Red Bluff, Alamogordo, and McMillan have original capacity losses at present of 5.2, 17, and 67 percent respectively. Red Bluff is the largest and is least affected at present by sediment deposition and would, therefore, receive the greatest benefits. Although Alamogordo Reservoir is appreciably depleted, it is an important economic unit, and any prolongation of its life would be worth while. McMillan is the oldest reservoir, and although the useful storage capacity is greatly reduced, it still functions as a regulator for irrigation releases.

221. It is assumed that the 43 percent reduction of sediment by a flood control program for the entire watershed, as shown in table 14, will also cause a corresponding reduction of sediment in reservoirs. This can be applied directly to Alamogordo and Red Bluff, but McMillan requires special consideration. The sediment is depositing largely in an area above spillway crest , and although it is not depleting remaining reservoir capacity, it supports a vegetative growth which causes large water losses. An appreciable part of the sediment now lying below present spillway crest was deposited above crest before the present dam and spillways were raised. However this vegetative area, consisting mainly of salt cedar, has considerable value as a sediment trap to prevent movement of sediment into Red Bluff Reservoir and other downstream areas.

222. The important effects of measures which will reduce sediment production are:

a. Prolong life of reservoirs.

b. Reduce filling and blocking of channels.

c. Reduce cost of maintenance to channels, ditches, and other structures.

d. Reduce deposition in areas which favor nonbeneficial use of water.

Effects of Program on Forage and Crop Production

223. General.—Due to the extent to which the watershed has deteriorated by the depletion of vegetation, erosion, and loss of soil structure, forage production is low. Plant vigor has been lowered and less desirable plants made up much of the present vegetative cover. The rehabilitation of range land by proper management, erosion control, structures, reseeding, and other measures recommended will improve forage production. Reseeding of denuded areas will speed up forage production. The application of conservation measures to dry-farm and irrigated land will increase crop production.

224. Forage production.—The recommended program will materially increase forage production on range and forest lands in the watershed. The installation of structures which will provide more favorable sites for forage production and the widespread adoption of good range management practices will provide vast improvement in the condition of the range.

225. Total forage production was first determined by relating clipping studies for several range condition classes with the various climatic and plant-soil conditions. Climatic conditions were expressed in terms of effective precipitation which is based upon such factors as relative humidity, temperature, and precipitation during the growing season. On the basis of the amount of effective precipitation, the watershed was divided into iso-climatic zones. Forage production curves were constructed for each range condition class, i. e., excellent, good, fair, and poor, by plotting forage yields from clipping studies against climate. These curves were used as a guide in estimating forage production in those portions of the watershed and those range condition classes where clipping studies had not been made. From these curves, forage production factors were determined for each iso-climatic zone and range condition class within each plant-soil group.

226. Forage production based on clipping studies does not show the amount of forage available for livestock use. From 40 to 60 percent of the forage produced should be left unused to maintain vigorous plants, soil stability, maximum infiltration, and minimum evaporation. An additional 10 to 25 percent is unavailable because it is inaccessible, is eaten by rodents, destroyed by trampling, or blown away. Thus only about 1/4 to 1/3 of the total forage produced is available for livestock use.

227. Forage production under future conditions was determined in the same way as for present conditions except that it was based upon the improvement in range condition classes that could be expected to result from the application of land treatment measures.

228. The results of studies showed that suitable land treatment measures will increase forage production by an estimated 66 percent.

229. Forage production can also be expected to be increased by the reseeding of 182,000 acres of depleted range land and seriously eroded farm land. The estimated annual production of available forage after stands are established is estimated at 55,000 tons.

230. Crop production.—The recommended program includes measures designed to reduce run-off and erosion on irrigated land. Results of a survey conducted in 1945 by the Soil Conservation Service show that the application of measures herein recommended and a high level of management increased crop yields by 15 percent. Yields on dry-farm land were reported to be increased by 25 percent.

BENEFITS OF THE RECOMMENDED PROGRAM

231. Monetary benefits.—The following types of monetary benefits resulting from the application of the recommended program are evaluated:

a. Reduction of floodwater damages as a result of decreasing the area and frequency of flood overflows.

b. Reduction of stream bank erosion of cropland by stream bank protection structures and plantings.

c. Reduction of sediment movement and reservoir sedimentation.

d. Change to higher land use.

e. Water conservation benefits resulting from increased availability of water for beneficial use.

f. Conservation benefits resulting from increased farm and ranch income from widespread application of conservation practices on watershed lands.

232. Basis for determining floodwater reduction benefits.—The benefits of the combined "going" and recommended program are the difference in the average annual floodwater damage under present conditions and the damages under future conditions when these programs are operative. Some of the benefits will result from measures carried out under "going programs." Accordingly, credit has been given to these portions of programs of Federal agencies which are related to the objectives of the Flood Control Act. To simplify calculations, benefits attributable to measures which will be carried out under "going programs" were determined on the basis of their proportion of the total cost of similar measures in the combined "going" and recommended programs. The benefits described in the following paragraphs and listed in tables 15 and 16 are those which are attributable to the program herein recommended. They make up 65.4 percent of the total benefits expected to accrue from the combined "going" and recommended programs.

233. Calculation of floodwater damage reduction benefits.—Floodwater reduction benefits are equal to the difference between the average annual floodwater damages occurring under present conditions and damages expected to occur under future conditions of reduced flood peaks. Estimates of future floodwater damages were calculated by applying the peak discharge damage relationships previously developed to the future flood frequency series.

234. The method used is illustrated by the following tabulation for the reach of the Pecos River from Alamogordo Dam downstream to the bridge crossing U. S. Highway 380 east of Roswell.

PERCENT OF YEARS PEAK FLOW IS EQUALLED OR EXCEEDED	PRESENT CONDITIONS		FUTURE CONDITIONS WITH PROGRAM	
	Peak Discharge	Calculated Damage	Peak Discharge	Calculated Damage
	cfs	$	cfs	$
20	18,000	32,000	12,700	0
10	27,000	178,000	19,200	51,400
4	41,000	403,000	28,500	202,000
2	52,000	508,000	37,200	341,000
11	64,000	775,000	44,200	455,000

Table 15 - ANNUAL FLOODWATER REDUCTION BENEFITS

Pecos River Watershed

Item	Annual damage present conditions	Annual damage w/program	Annual benefits total program 1/	Annual benefits recommended program
PECOS RIVER				
Above Alamogordo Reservoir	$ 92,800	$ 35,200	$ 57,600	$ 48,200
Alamogordo to Roswell	64,200	19,100	45,100	35,900
Roswell to Lake McMillan	157,500	72,700	84,800	68,600
McMillan to Red Bluff	5,200	3,200	2,000	1,300
Red Bluff to Girvin, Texas	53,700	34,500	19,200	13,800
Total	$373,400	$164,700	$208,700	$167,800
TRIBUTARIES				
Rio Hondo	$ 83,800	$ 10,800	$ 73,000	$ 67,000
Rio Felix	11,500	6,400	5,100	3,300
Rio Penasco	18,100	7,000	11,100	7,300
Toyah Creek and vicinity	32,600	15,500	17,100	13,500
Other tributaries	35,800	18,200	17,600	11,600
Total	$181,800	$ 57,900	$123,900	$102,700
Total floodwater reduction benefits	$555,200	$222,600	$332,600	$270,500 2/

1/ Total program consists of the combination of going programs and the recommended program.

2/ Floodwater reduction benefits on the Rio Hondo below Hondo Reservoir and on Dark Canyon are not evaluated.

Floods of 16,000 cfs or less in this reach are considered to be nondamaging. Hence, no damage is shown for floods of this magnitude. The reduction of flood peaks and frequency of damaging floods will reduce the average annual floodwater inundation damage from an estimated $45,700 to $19,100. The average annual floodwater reduction benefit is $26,600. This reduction in damages is attributable both to the "going" program and recommended program. On the basis outlined in paragraph 232, the recommended program is credited with 65.4 percent or $17,400. This does not include benefits due to a reduction in the rate of stream bank erosion. For purposes of this analysis it is not assumed that reduction in flood peaks alone will have a significant effect on the rate of stream bank erosion. To solve the stream bank erosion problem in this reach of the river, protection measures are recommended. It is estimated that the benefits of the proposed work will be $18,500 annually. The total floodwater reduction benefits attributable to recommended measures in this reach of the river are estimated at $35,900 annually (table 15).

235. In the Alamogordo to Roswell reach of the river no flood control structures are planned to reduce the area or frequency of flooding. In other areas where major flood control measures are feasible, floodwater reduction benefits were determined by routing the reduced flood peaks through the structures (detention dams, flood channels, etc.) and the residual damages calculated from the reduced flood peaks.

236. Stream bank protection is considered necessary to reduce the rate of stream bank erosion. Furthermore, in those areas where such measures are feasible, it is considered that stream bank erosion would be halted. Where stream bank protection measures were determined to be infeasible, no reduction in the rate of stream bank erosion is evaluated.

237. The reduction of floodwater damages is shown in table 15. Because of greater flood peak reductions in the headwaters and on tributaries, greater reductions in flood damages will occur in these areas.

238. Reservoir sedimentation reduction benefits.—It is estimated that the combination of measures herein recommended, plus the measures applied during the installation period under the going programs will reduce rates of reservoir sedimentation by about 43 percent. This will result in less frequent replacement of reservoirs and smaller reductions of water supplies arising from capacity depletion. The monetary benefits of these changes were computed on the same basis as was the sediment damage to irrigation reservoirs under present conditions, but using the expected future rate of sedimentation. The sediment damage under future sedimentation rates was deducted from the damage under present sedimentation rates and the difference credited as a benefit.

239. The reduction of the sedimentation rate of Alamogordo Reservoir by 43 percent will extend the useful life of the reservoir by only about 39 percent. At the same time, however, the reduction in water supply due to sedimentation will be only 72 percent as great. Similar effects are expected at other reservoirs.

240. Sedimentation damages under present conditions are estimated at $377,800 per year. The benefit due to the recommended program is estimated to be about $89,200 annually.

241. Change to higher land use.--It can be expected that the reduction of the area and frequency of flooding will result in some shifts in land use. These shifts are not expected to be large because the existing flood hazard in most instances is not a major determinant of land use. However, there are some areas where the evidence is quite conclusive that shifts to less intensive land use have occurred primarily as a result of repeated flooding and that removal or reduction of the flood hazard will result in shifts to higher land use. This evidence is substantiated by farmer opinion. Most notable of these areas lie along the Rio Bonito where 582 acres of irrigated land are now idle or cultivated intermittently because it is impractical to install adequate irrigation structures that would be subject to frequent washouts under present conditions.

242. The reduction of the flood hazard to an area along the Rio Bonito by constructing a detention dam on Salado Creek, a tributary, will permit the redevelopment and intensive use of land for crop production under irrigation. This area is adapted to the production of fruit and some of the land would be planted to orchards. Other crops such as alfalfa and corn would be grown. The estimated benefit of the conversion to cropland from pasture or idle land of 582 acres is $17,000.

243. Water conservation benefits.--An analysis of the effect of the recommended program on water yields indicates a net gain in the amount of water available for irrigation. The watershed improvement program will reduce flood volumes. This will have no effect on water supplies derived by direct diversion but will affect water supplies dependent on storage of floodwaters. Red Bluff Reservoir is the lowest channel reservoir on the Pecos. Consequently the reduction in flood volumes is calculated only for the watershed above Red Bluff. The Balmorhea project stores some floodwater but inasmuch as this is an off-channel diversion, no decrease in diverted water is anticipated. Recharge of underground water is expected to increase by prolonged flood flows through the recharge area. The removal of salt cedar at the head of Lake McMillan will release a considerable amount of water for beneficial

use. The net effect of the complete program on water supply is an estimated increase of 12,000 acre-feet as follows (par. 216-217).

Reduction of water supply by watershed treatment	11,000 acre-feet
Increased recharge, underground water and seepage	2,000 acre-feet
Net effect of watershed program (decrease)	9,000 acre-feet
Salt cedar control (increase)	21,000 acre-feet
Net effect of entire program (increase)	12,000 acre-feet

244. It is expected that the additional water will have a stabilizing effect on water supplies for areas now irrigated. Development of additional land would not be wise at this time. The benefit derived from increasing the water supply is evaluated on the basis of the resulting increased crop production. The net benefit of salvaging 12,000 acre-feet of water for beneficial use is estimated to be $189,000 annually, using the value of water shown in paragraph 165.

245. Range and forest conservation benefits.—Conservation use of forage and timber resources is essential to the improvement in vegetative cover which must be attained to accomplish the estimated floodwater and sediment reduction benefits. Under proper range management, vegetation will improve in vigor, density and composition. These improvements in vegetative condition will aid in holding the soil in place and increase the amount of precipitation absorbed by the soil. The installation of stabilizing structures will permit the rehabilitation of gullied areas so that they will become productive. Suitable grazing practices are necessary for the effective operation of terraces and diversions while vegetation is becoming established in the treated areas. Range conservation benefits accrue from the additional forage which will be available for livestock grazing as a result of the application of land treatment measures. All of the forage increase is not available for livestock use. The percentage that can be grazed safely is discussed in paragraph 226.

246. It is estimated that the improvement of vegetative cover will increase the amount of available forage on about 10 million acres of grazing land by about 417,000 tons. By reseeding about 182,000

acres of abandoned crop land and depleted range land, an additional 55,000 tons of forage will be produced. The total increase in forage production is estimated at 472,000 tons annually. This improvement in forage production presupposes a level of management and degree of grazing use necessary to attain program objectives. It is estimated that one ton of forage will produce about 72 pounds of beef (or its equivalent in mutton or wool). At 1948 prices, the gross value of one ton of forage in beef equivalent is estimated at $15.74. For comparative purposes, the price of baled alfalfa hay in 1948 in New Mexico varied between $25 and $31.50 per ton. Production expenses such as labor, taxes, interest, improvements, management, and miscellaneous expense are estimated at $7.22 per ton of forage harvested. The net return to land is estimated at $8.52 per ton of forage harvested.

247. The application of additional fire control measures is expected to reduce the incidence and extent of burns in forested and grazing areas. This will result in the saving of timber, grass, and other watershed resources. Deterioration of the watershed will be reduced. More intensive fire control will reduce the cost of fire suppression. Fires will be detected sooner and fire fighting personnel and equipment will get to the site quicker because of greater mobility. Greater emphasis will be given to fire prevention work as a means of reducing losses. Data pertaining to damage to forest resources, watershed values, and costs of fire suppression are available for the area within national forests. This information was used to estimate the benefits of the fire control program.

248. The area of timber burned annually in the watershed is estimated at 1,200 acres. The damage to timber resources averages about $16.15 per acre, resulting in a loss of $19,400 each year. It is estimated that losses due to large fires can be reduced by 75 percent, and losses due to small fires can be reduced by 10 percent. The reduction in area burned will also protect some watershed values by preventing deterioration which results when forest cover is destroyed. The watershed values of the timbered portion of areas is estimated at $25 per acre.

249. The total conservation benefits of the recommended program which will accrue to range and forest land is estimated at $4,057,500

250. <u>Conservation benefits on dry-farm land.</u>--The measures recommended herein will materially increase crop yields on nonirrigated land. It is estimated that conservation measures proposed for 56,000 acres of dry land will increase yields by an average of 25 percent. The increase in net value of crops is estimated to be $3.25 per acre. The benefits attributable to measures herein recommended are estimated at $182,000.

251. Conservation benefits on irrigated farm land.—Crop production on irrigated land will be increased by the use of suitable conservation measures. The measures specifically recommended herein for treatment of 50,000 acres of irrigated lands which are contributing floodwater and sediment will increase yields from those lands by 15 percent. The additional income is estimated at $15.00 per acre.

252. It is believed that the installation of recommended measures will effect a saving in farm labor costs which will more than offset higher harvesting cost due to greater yields. The net annual conservation benefit attributable to the installation of the recommended program on irrigated land is estimated at $750,000.

253. Total monetary benefits for the watershed.—The installation of the recommended program in the interest of flood control will ultimately result in benefits estimated at $5,555,200 annually (table 16).

Table 16 - TOTAL ANNUAL MONETARY BENEFITS

Pecos River Watershed

FLOOD AND SEDIMENT BENEFITS	
Flood reduction	$ 270,500
Sediment reduction	89,200
Subtotal	359,700
OTHER BENEFITS	
Change in land use	17,000
Water conservation	189,000
Range and forest conservation	4,057,500
Dry-farm land	182,000
Irrigated farm land	750,000
Subtotal	5,195,500
TOTAL - All Monetary Benefits	$5,555,200 1/

1/ Based on 1948 prices.

NON-MONETARY BENEFITS

254. In addition to the monetary benefits which have been evaluated, the proposed remedial program will provide numerous other benefits. These benefits include reductions in the degree or amount of damages listed in paragraph 171. Important benefits in this class are: prevention of loss of life, relief from worry and discomfort, prevention of interruption in transportation and communication. Representatives of the Fish and Wildlife Service consulted during preparation of this report have informally advised that the program as outlined would result in substantial benefits, particularly to upland game. This is especially true if the state agencies concerned and the Fish and Wildlife Service assist in the planning and application of land treatment measures.

COST-BENEFIT ANALYSIS

255. Price and cost levels.—Converting 1948 prices and costs to those expected to prevail under an intermediate level of employment, the index of prices and costs shown in table 17 were used.

Table 17 - INDEX OF PRICES AND COSTS

Pecos River Watershed

Item	1948 Index	Avg. Index	Adj. Factor 1948 to Avg.
Index of prices rec'd by farmers USDA index (1910 - 1914 = 100)	287	150	.523
Index of prices paid by farmers USDA index (1910 - 1914 = 100)	249	165	.663
Index of construction costs earthwork - ICC index (1910 - 1914 = 100)	159	122	.767
Index of other construction costs Engineering News Record index (1913 = 100)	461	325	.705

256. In terms of past prices and costs these average indexes are about the same as the 1940-44 average of prices received by farmers, 1942-46 prices paid by farmers, and 1943-47 construction costs.

257. Analysis of program by types of measures.—In addition to determining the feasibility of the entire program under average price and cost levels, the benefit-cost analysis includes tests of feasibility of the following groups of measures:

1. Interdependent land treatment measures.

2. Independent additional flood control measures, which include:

    a. Channel improvement.
    b. Stream bank protection.
    c. Floodway systems.
    d. Capitan detention dam.

3. Water conservation measures which include salt cedar control for the purpose of offsetting the expected reduction in run-off for watershed land.

258. Distribution of program benefits.--The benefits of the various types of recommended measures are shown in table 18.

Table 18 - AVERAGE ANNUAL BENEFITS OF THE RECOMMENDED PROGRAM

Pecos River Watershed

(Normal Prices)

	Flood-water reduction	Sedi- 1/ ment reduction	Water conservation	Other conservation	Change in land use	Total benefits
	$	$	$	$	$	$
INTERDEPENDENT LAND TREATMENT MEASURES	74,600	50,800	-	2,132,000	-	2,257,400
ADDITIONAL MEASURES NEEDED FOR FLOOD CONTROL						
Stream bank protection	43,900	1,500	-	-	-	45,400
Channel improvement	10,100	-	-	-	-	10,100
Floodway systems	17,800	-	-	-	-	17,800
Capitan detention dam	10,800	1,400	-	-	7,200	19,400
Subtotal	82,600	2,900	-	-	7,200	92,700
WATER CONSERVATION MEASURES	-	-	81,600	-	-	81,600
TOTAL - All Measures	157,200	53,700	81,600	2,132,000	7,200	2,431,700

1/ Benefit of reducing sedimentation of reservoirs.

259. Distribution of costs.--On the basis of average costs, the installation of the recommended program will cost $16,021,000, or about 20 percent less than the 1948 costs. The distribution of these costs, together with their annual equivalent value, is shown in table 19.

Table 19 - COST OF THE RECOMMENDED PROGRAM

Pecos River Watershed

MEASURE	INSTALLATION	ANNUAL COST		
		Operation & maintenance	Installation	Total
INTERDEPENDENT LAND TREATMENT MEASURES	$13,757,400	$188,400	$397,300	$585,700
ADDITIONAL MEASURES NEEDED FOR FLOOD CONTROL				
Stream bank protection	767,200	21,500	20,500	42,000
Channel improvement	132,700	3,200	3,600	6,800
Floodway systems	249,300	3,700	6,600	10,300
Capitan detention dam	309,100	1,700	8,100	9,800
Subtotal	1,458,300	30,100	38,800	68,900
WATER CONSERVATION MEASURES				
Salt cedar eradication	805,300	26,800	21,100	47,900
TOTAL - All Measures	$16,021,000	245,300	457,200	702,500

260. Land treatment measures account for about 83 percent of the total cost, whereas the cost of measures needed primarily for flood control amount to 10 percent and water conservation measures 7 percent.

261. Comparison of benefits and costs.--All measures or groups of measures in the recommended program have a benefit-cost ratio in excess of 1 to 1 (table 20). The benefit-cost ratio for the entire program is estimated at 3.5 to 1. The ratios vary from a low of 1.1 to 1 for stream bank protection to a high of 3.9 to 1 for land treatment measures.

Table 20 - COMPARISON OF BENEFITS AND COSTS

Pecos River Watershed

Measure	Average Annual Benefit	Average Annual Cost	Benefit-Cost Ratio
INTERDEPENDENT LAND TREATMENT MEASURES	$2,257,400	$585,700	3.9 : 1
ADDITIONAL MEASURES NEEDED FOR FLOOD CONTROL			
Stream bank protection	45,400	42,000	1.1 : 1
Channel improvement	10,100	6,800	1.5 : 1
Floodway systems	17,800	10,300	1.7 : 1
Capitan detention dam	19,400	9,800	2.0 : 1
Subtotal	92,700	68,900	1.3 : 1
WATER CONSERVATION MEASURES			
Salt cedar control	81,600	47,900	1.7 : 1
TOTAL - All measures	$2,431,700	$702,500	3.5 : 1

BIBLIOGRAPHY

1. Brown, Carl B.
   The Control of Reservoir Silting; Misc. Publications No. 521, U. S. Department of Agriculture, 1944.

2. Brown, Carl B.
   Rates of Sediment Production in Southwestern United States; SCS-TP-58, U. S. Department of Agriculture, Soil Conservation Service, January 1945.

3. Culley, Matt J.
   An Economic Study of Cattle Business on a Southwestern Semidesert Range; Circular 448, U. S. Department of Agriculture, December 1937.

4. Dorroh, J. H. Jr.
   Certain Hydrologic and Climatic Characteristics of the Southwest; University of New Mexico Press, 1946.

5. Eakin, Henry M. (Revision by Carl B. Brown)
   Silting of Reservoirs; Tech. Bulletin No. 524, revised August 1939, U. S. Department of Agriculture, 1939.

6. Fenneman, N. M.
   Physiography of Western United States; New York and London, 1931.

7. Fiedler, A. G. and Nye, S. S.
   Geology and Ground Water Resources of the Roswell Artesian Basin, New Mexico; U. S. Geological Survey Water Supply Paper No. 639, 1933.

8. Fiedler, A. G., and Nye, S. S.
   Ground-water Investigation of the Roswell Artesian Basin, New Mexico; Eighth Biennial Report, State Engineer of New Mexico, 1926-28.

9. Happ, Stafford C., Rittenhouse, G., and Dobson, G. C.
   Some Principles of Accelerated Stream and Valley Sedimentation; Tech. Bulletin No. 695, U. S. Department of Agriculture, May 1940.

10. King, Robert E., et al.
    Resume of Geology of the South Permian Basin, Texas and New Mexico; Bulletin Geological Society of America, Vol. 53, No. 4.

21. Theis, C. V.
Origin of Water in Major Johnson Springs Near Carlsbad, New Mexico; Twelfth and Thirteenth Biennial Reports, New Mexico State Engineer office, 1934-38.

22. Transcript of Public Hearings on Pecos River Watershed, Santa Fe and Roswell, New Mexico; unpublished, 1938.

23. U. S. Department of Agriculture.
Agricultural Statistics (Yearly Summaries, 1932-48).

24. U. S. Department of Agriculture, Bureau of Agricultural Economics.
Crop and Marketing Reports (1932-48).

25. U. S. Department of Agriculture, Bureau of Agricultural Economics, Water Utilization Section, Division of Land Economics.
Water Facilities Area Plan for Toyah Creek Watershed, Texas; October 1940.

26. U. S. Department of Agriculture, Forest Service.
Annual Report of the Southwestern Forest and Range Experiment Station, Calendar Year 1946; mimeographed.

27. U. S. Department of Agriculture, Forest Service, Region 3.
Unpublished reports and records, 1936-47.

28. U. S. Department of Agriculture, Forest Service and Soil Conservation Service.
Influences of Vegetation and Watershed Treatments on Run-off, Silting, and Stream Flow; Miscellaneous Publication No. 397, 1940.

29. U. S. Department of Agriculture, Soil Conservation Service, Region 6.
Unpublished reports and records, 1936-1947.

30. U. S. Department of Commerce, Bureau of Census.
Population - 1940; Agriculture - 1945.

31. U. S. Department of Commerce, Weather Bureau.
Climatological Data; Texas and New Mexico Sections, 1892-1947.

32. U. S. Department of Commerce, Weather Bureau, in cooperation with War Department, Corps of Engineers, U. S. Army.
Hydrologic Bulletin, Hourly and Daily Precipitation, Lower Mississippi-West Gulf District; 1940-1947.

33. U. S. Department of Interior, Bureau of Reclamation, Region 5.
Plan for rehabilitation, Fort Sumner Project; Project Planning Report No. 5-15.7-1, January 1947.

34. U. S. Department of Interior, Geological Survey.
Surface Water Supply of the United States - Western Gulf of Mexico Basins, Part 8; United States Government Printing Office, 1888-1945.

35. U. S. Department of Interior.
Geological Survey Bulletin No. 845; Guidebook of the Western United States, Part F, Southern Pacific Railroad Lines, N. H. Darton.

36. U. S. Department of War, Corps of Engineers, District Office, Albuquerque, New Mexico.
Unpublished reports and records, 1944.

37. U. S. Department of War, Corps of Engineers, U. S. Engineer Office, Albuquerque, New Mexico.
Sedimentation in Conchas Reservoir; Interim Report, September 1943.

38. U. S. National Resources Planning Board.
The Pecos River Joint Investigation; U. S. Government Printing Office, 1942.

39. U. S. National Resources Planning Board.
Regional Planning, Part X - Pecos River Basin, June 1942.

40. Weaver, John E., and Clements, Fredric E.
Plant Ecology; McGraw-Hill Book Co., 1929.

41. White, W. N., Gale, H. S., and Nye, S. S.
Geology and Ground-water Resources of the Balmorhea Area, West Texas; U. S. Geological Survey Water Supply Paper No. 849-C.

42. Wisler, C. O., and Brater, E. F.
Hydrology; John Wiley & Sons, 1949, p. 20.

43. Yarnell, David L.
Rainfall Intensity-Frequency Data; U. S. Department of Agriculture Miscellaneous Publications No. 204, 1935.

44. Yeo, H. W., et al.
Report on Floods in the Pecos Valley in New Mexico; Unpublished, U. S. Department of Agriculture, Soil Conservation Service, 1937.

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